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DEVOTED TO

SCIENCE AND THE MECHANIC ARTS

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BY-PRODUCTS IN GAS MANUFACTURE.[1]

BY

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In dealing with the interesting topic which has been assigned me in this Centennial Celebration it seems proper, and in the interest of clearness of treatment, to deal broadly with the subject of by-products before dealing with those of the Gas Industry. I have, but a short time ago, been called on to prepare an article on this subject for the Loose Leaf Encyclopædia, and with your permission I will quote part of this article, since I feel that I have therein presented the matter to the best of my ability.

"By-products are substances or results obtained in the operation of a specific process, in addition to the substance or result

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[1] Address delivered at the Celebration of the Centenary of the Introduction of Gas as an Illuminant, under the auspices of The American Philosophical Society, The Franklin Institute, The American Chemical Society, and The American Gas Institute, in the hall of the Franklin Institute, Philadelphia, on Thursday, April 18, 1912.

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primarily sought. In hunting game for food, the hides and feathers are by-products; in hunting game for hides or pelts, the carcasses are by-products; in manufacturing lumber, the sawdust and shavings are by-products; in brewing beer, the yeast is a by-product.

" In the classification of the products of manufacture, three groups are recognized—viz., *principal product,* which is that product of an establishment manufacturing more than a single product that has the largest total value; *subsidiary product,* which is a product of such an establishment having a less total value; and *by-product.* A subsidiary product may be a utilized by-product, or it may be the product of an allied industry—as, for instance, bookbinding in a printing office, or compounding fertilizers in a cottonseed-oil mill. This last example is one of many occurring in factories where the by-product of the principal industry—in this case cottonseed meal—becomes the raw material for the manufacture of a subsidiary product. The development and growth of manufactories using manufactured products as the raw material for further manufacture has not infrequently created such a change in the demand for the products of the primary establishment as to make one of its subsidiary products its primary product. A notable example of this is the Le Blanc process for the manufacture of soda products from common salt by the action upon it, in the first stage of manufacture, of sulphuric acid. In this operation, hydrochloric acid gas is given off as a by-product. At first this was wasted by being allowed to escape into the atmosphere, where it produced most devastating effects. To avoid the nuisance thus created, this gas was collected by dissolving it in water, and sold, thus becoming a subsidiary product; but with a greatly increased demand for this substance, for the manufacture of bleaching powder and other uses, through which its value was enhanced, and with the competition of electrolytic and other processes, through which the cost of the production of sodas was reduced, hydrochloric acid became in many cases the principal product of the Le Blanc factories.

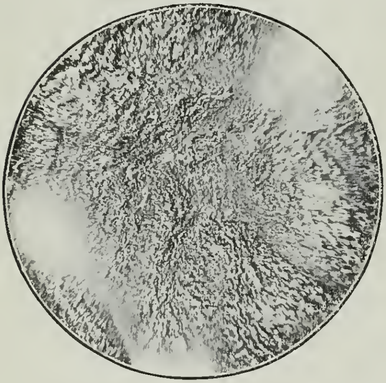
" As indicated by the examples cited, the custom of utilizing by-products is a very ancient one in its origin, though frequently in the newer countries, where the raw material was abundant, or in the early development of industries, where the unit of production was small and competition slight, the by-products have generally been wasted, and frequently have become sources of nuisances. But with the increase in density of the population, through which the necessity for abating the nuisances became urgent; with the increase in the unit of production; with a diminution in the quantity of the raw material, or the ease with which it could be obtained; and with the increase in competition, additional attention has been given to the utilization of the by-products of manufacture, until to-day they have become of great importance in all industries, and of such commercial value that the creation and maintenance of many establishments have been determined by the ability to utilize and dispose of the by-products of their processes.

"Naturally, the by-products that were first to be utilized were those which were most readily observed and whose uses were most obvious. The by-products which ran off in solution or passed away as gases, or forms of energy, such as heat, or those whose uses were remote or less readily apparent, have until very recent times been allowed to go to waste. The discovery of the first of the aniline coloring matters, mauve, in 1856, by the English chemist William Henry Perkin, and the fact that the aniline from which it is manufactured could be obtained in abundance from coal tar, gave an impetus to the utilization of the last enumerated by-product; and the rapid growth in commercial importance of the coal-tar products industry so concentrated attention on this phase of manufacture that the utilization of by-products has gone on with increasing expansion ever since."

There exists a rather widely extended popular belief that the "coal-tar colors"; many perfumes, flavors and synthetic drugs; and numerous other substances, are by-products of the gas industry, but such is not the case, for they are produced by the further manufacture of the by-products of this industry. This view limits the scope of my topic, which is, however, broadened by the modern view of the gas industry in that it embraces in its consideration not only coal gas, but all gases manufactured for the generation of light, heat or power and which are distributed for use by public service organizations. All of the processes of manufacture employed in the production of these gases depend upon the chemical transformation of the materials used, and in all processes other products beside the gas sought are yielded.

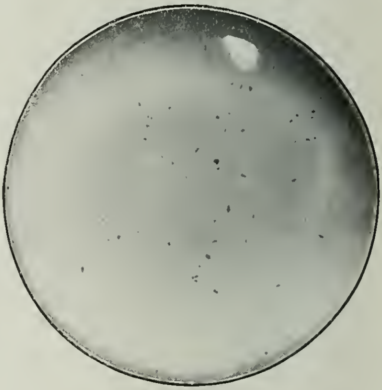
This is particularly true in the carbonization or, using the more precise chemical term, the thermolysis, of peat, wood, resin, coal, oils, and other organic bodies, in which these bodies are subjected to widely ranging degrees of temperature and quantities of heat when enclosed in containers, such as retorts, ovens, or kilns, which more or less completely prevent access of air to these bodies during the thermolyzation process, and which are so operated that the heat, which effects the thermolysis, is conveyed to them through the walls of the containing vessel. For these bodies are complexes. The simplest of them, such as the resins, produced from exudates from deciduous vegetation or the thermolyzation of such exudates, and the distillates of petroleum, are still complexes. They are not elementary. They are not even single chemical compounds, but they are aggregates of chemical compounds each of which is capable, under certain conditions of temperature and pressure, of undergoing a particular kind of decomposition with the production of certain particular products, each of which, were they to remain apart, might be of such character as to form a useful product, but, being mixed, or associated with other products the tendency is that these intermediate products of thermolysis react with one another and that the final product, which may be, and usually is, a mixed

FIG. 1.



Coal gas tar.

FIG. 2.



Water gas tar.

product, is a final integration of the process as it has proceeded from its initial condition, through its manifold transformations, to its end condition.

The conditions described are those which especially obtain for coal, as known in England, or bituminous coal as it is styled in the United States. This is the substance which first met with general success and which is yet to-day largely used in the manufacture of gas. It is the substance from which coal gas, so styled, has been and still is produced and though commercially regarded as, and popularly believed to be a definite and individual substance it is not so, for it not only varies in its composition, constitution and characteristics as it is obtained from different localities, but it varies by degrees as it is obtained from different geological deposits in the same geographical locality and may even vary in the deposits of the same geologic age, or, in technical parlance, of the same seam, according to the conditions to which it has been subjected. The vicissitudes to which coal forming materials are subjected in this conversion from cryptogamous vegetation, such as prevails in peat, or phenogamous vegetation in its many species, through lignite into coal, is admirably portrayed by Dr. T. E. Thorpe[2] and the manifest complexity and variability of the product is there well indicated. The geological significance of these transformations of vegetation are set forth by J. D. Dana in that charming, yet accurate style, of which he was a master.

Notwithstanding this recognition of complexity we have known nothing definitely as to the constitution of coal or of the nature or amount of its components. A large number of ultimate analyses, showing the percentages of carbon, hydrogen, oxygen and nitrogen present in ash-free coal, have been made and recorded in literature, as have also many proximate analyses giving the percentages of moisture volatiles, coke, or fixed carbon, and ash, with the sulphur and phosphorus contents. Such data has had and still has an economic value in gas making and coke making and in the utilization of the coal, or some of its products, in iron smelting or steel working, but it still leaves us uninformed as to what there is in the different varieties of coal or in any given coal. And we are not much further enlightened by the interesting comparison made by Pennock,[3] and others, of the character and composition of the tars yielded by different coals whose proximate compositions had been precisely determined, for these tars were the products of thermolysis, accompanied no doubt by metathetical changes also.

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[2] "Coal: Its History and Uses." Macmillan & Co., London, 1878.

It has long been known that peat, lignite and bituminous coal, certainly, are affected by some solvents. In the early days of my professional career I devised a scheme for the classification of coal producing substances, and the different varieties of coal, based on the character of the colors which they imparted to aqueous potassium hydroxide solutions in which the powdered material had been digested. There is some question in this case as to whether the extracted matter was identical with that in the coal or whether it had chemically reacted with the strongly alkaline reagent used. It is known, however, that we have many neutral liquids such as alcohol, benzene, ether, chloroform, acetone, carbon tetrachloride, carbon disulphide, pyridine, ligroin and other petroleum distillates, to mention but a few at com-

FIG. 3.

Benzol plant.

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[3] J. D. Pennock, *J. Am. Chem. Soc.*, 21, 696, 1899.

mand, which are solvents of organic substances, through which hydrocarbons and their derivatives which may be present in the coal can be extracted unchanged, while by the action of reagents of known behavior, such as nitric acid, chlorine, caustic alkalies in the molten condition and the like, derivatives of these organic substances, whose genetic relationships are known, may be obtained, and thereby, through both direct and indirect methods of approach, the constitution be ascertained.

Records of the attempts made to solve this problem of the constitution of coal, by means such as described with the results thus far obtained, have been assembled and critically reviewed in a masterly manner by Frank Wiggleworth Clarke in his "Data of Geochemistry,"[4] and it can only be said that the results are most meager, largely because the extractives are usually tars which require further treatment for separation and identification, by slow and tedious processes and that the total yields are rarely large. It may be of interest to announce that the recently created U. S. Bureau of Mines has taken up this problem as one of its studies looking to a more complete and economic utilization of our coal and therefore to the conservation of our fuel resources, and that the results of the preliminary investigations on these lines by J. C. W. Frazer and E. J. Hoffman, of that Bureau, have been prepared for publication. I feel assured that as more definite information is acquired the character of our distillation processes, such as are now used in gas and coke making, will be profoundly modified and that the nature and yields of the by-products of the gas industry will be materially changed.

Taking the industry as it has been and now is, it may be noted that the by-products of the coal gas industry are coke, gas, carbon, tar, ammoniacal liquor and spent purifying material, either lime or oxide. In the water gas industry tar and purifying material, with a meager amount of ammoniacal liquor. In the oil gas industry lampblack, tar and spent purifying material for the new Lowe process, and "hydrocarbons" for the cracked and compressed oil gases. While in the acetylene gas industry calcium hydroxide is practically the only product incidental to the reaction other than the acetylene.

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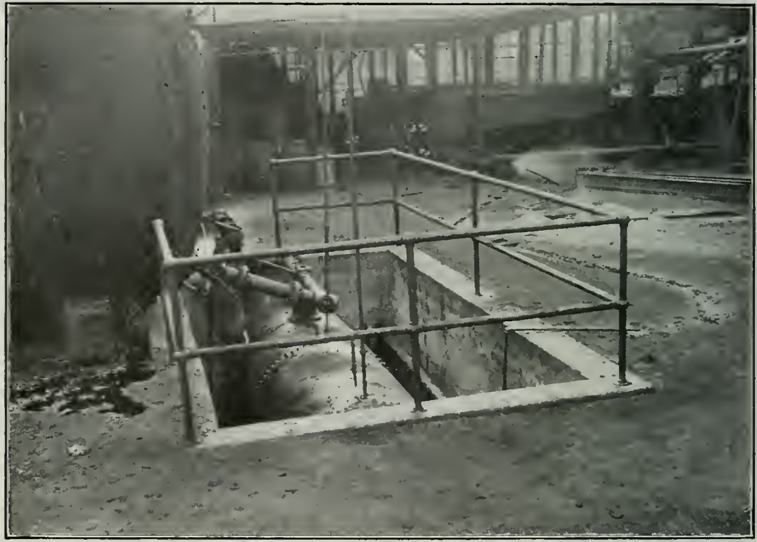
[4] Bulletin 491 (2d ed.) U. S. Geological Survey, pp. 705-731, 1911.

From the outset the commercial and economic value of certain of the collateral products obtained from the chemical reactions which yield coal gas were recognized, and to such an extent that the original organization, whose parliamentary recognition we now celebrate as a significant event in the evolution of chemical industries, was styled the "Chartered Gaslight and Coke Company"; the production of coke, by the distillation process employed apparently being regarded by Winsor and his associates, as of equal, or nearly equal industrial importance to that of coal gas. We know that in the last quarter century the relative economic importance of the gas and coke obtained from bituminous coal by distillation processes has been, and to-day still is, in many localities or under certain industrial conditions, reversed, and that where by-product coke ovens are employed the coke is the principal product and coal gas is one of the subsidiary by-products. In by-product coke making, particularly where gas is supplied to public service corporations, for distribution, as is often the case, the other by-products are substantially those of the coal gas industry.

FIG 4.



Blow case.

I say "substantially" with intent for they would be identical only by the most remote chance since it is recognized that, using the same coal, the products obtained differ in quantity and character when thermolyzed in the same retort with variations in the rate, degree and method of heating them, and with the pressures put upon, and that when the device employed, such as vertical or inclined retorts, or ovens of the many dimensions and forms known, is substituted for the horizontal retort of standard type, the conditions under which the thermolyses and metatheses take place are so varied that the products are materially varied both in composition and quantity, and this difference is emphasized when the material treated differs, as does coal from different localities or even from the same locality but from different parts of the vein.

Fig. 5.

Refined storage tanks.

My presentation of the difficulties which beset the gas manufacturer in his endeavor to produce a gas of uniform character that will conform to the regulations or restrictions placed on him by the state or municipal legislation or ordinance with which he is environed may perhaps have quickened your interest or stimulated your incredulity. If so this part of my thesis is completed.

But I call attention to the fact that complex and variable as the gaseous products of soft coal distillation are, the tar and ammoniacal liquor which are by-products are subject to as marked variations in yields or in composition or both with differences in the coal used and the processes or devices employed and in their operation as the gas is and that these, but more particularly the tar, are the by-products which have lent special interest to the gas industry and which in the more recent years have proved to be important factors in its commercial success and in enabling this industry to maintain its place commercially in the presence of competing illuminants.

Of these by-products the ammoniacal liquor is chemically the simplest and yet it is complex and variable. It is produced from some of the nitrogen in the coal, and perhaps to a degree, when alkalies or alkaline earths are present from atmospheric nitrogen entering, or included in the chamber in which the destructive distillation of the coal is effected. Varying with the process employed and its operation the ammonia content appears in the condensates as carbonate, sulphide or polysulphide, chloride, cyanide, sulphocyanide, and probably in other combinations, from which it is released, to a greater or less extent, by the action of stronger hydroxides, such as calcium hydroxide, in the process of recovery when it is converted into the marketable forms of ammonia water or ammonium sulphate.

In this latter state of combination the nitrogen of the coal or the atmospheric nitrogen which has entered into this state of combination, has become available for food for vegetation, whereas before it was not so. This forcibly illustrates the correlation of country and city, of agriculture and manufacture, for while the coal remained unmined its nitrogen content was unavailable as plant food, but when that coal had been mined and employed in the manufacture of gas for city or town lighting its nitrogen content was not only released from its inert condition of combination but brought into such association, through subsequent treatment, as to be available for plant food. To-day a larger part of the available nitrogen necessary for use in compounded fertilizers or for direct use in agriculture comes from the gas industry, or from its closely correlated industry, the by-product coke industry.

The utilization of ammonium sulphate from the gas industry in agriculture practically dates from the time of the governmental encouragement of the beet-root sugar industry in Germany. It is in this way correlated with the potash industry which has been so recently a serious topic for diplomatic negotiations and which to-day remains a grave problem for governmental solution. Personally I find the available nitrogen question to be a wider one than that of agriculture. I find it to be closely concerned with the ability of a nation to protect and defend itself in a prolonged warfare. I find that in the immediate past and to-day the supposed dominant nations have been and are, through the necessity for available nitrogen in warfare, dependent nations since they have sought for this available nitrogen the few sources of supply where it has been stored by nature's agencies working in a comparatively simple manner. I have elsewhere suggested [5] that chemistry has in recent years released these nations from their state of dependency. It seems at first thought a far cry from the manufacture of gas, by which to extend the efficiency and efforts of the people of a nation, to its defense in time of attack, but chemistry has made this last relation relatively close and the gas industry, if properly directed, may reasonably be expected to become a factor in the defense of the nation and its managers may rightly feel that in wisely and justly directing the affairs of a gas company they are not only rendering a public service but a patriotic service also.

In the development of the ammonia recovery from coal gas a rather amusing and curious condition has developed. Originating as the gas industry did in England that country has maintained its supremacy in the production of by-products and when ammonia and ammoniacal compounds from this source began to assume economic importance there was devised in England a means for ascertaining the quantity of the valued component in a liquor by liberating it from its state of combination, through the aid of calcium hydroxide, and then measuring its neutralization with a standard solution of sulphuric acid which had been made up on the scale of Winchester gallons. This method of determining the ammonia content of liquors, known as "ounce-strength," was on its face obviously fair and equitable and was shortly afterwards introduced into this country, but the difference in measures was overlooked and the standard sulphuric acid was made up with the U. S. gallon as the measure and ever since " ounce-strength " has had in the United States a different significance from that which it has had in England. Fortunately the content in real NH_3 or $(NH_4)_2SO_4$ is coming more commonly into use and the discrepancy of statistics which has existed between different countries is being reconciled.

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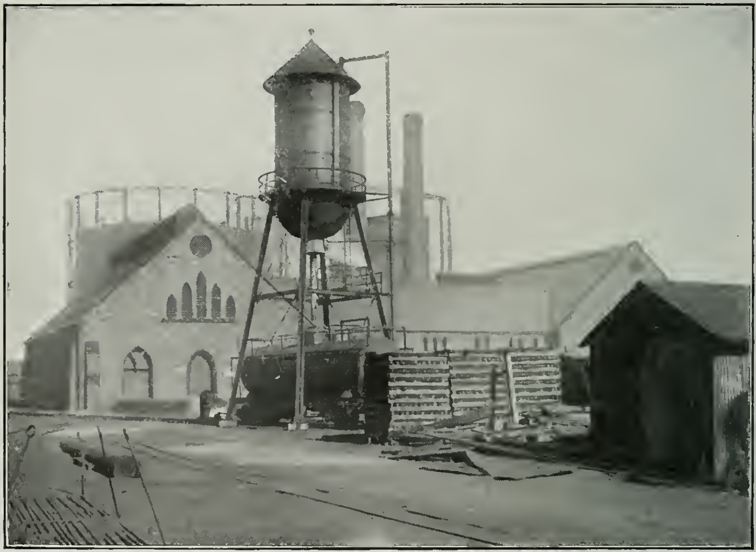
[5] "The Nitrogen Question from the Military Standpoint," U. S. Naval Inst., Proc. 35, 715, 1908. Smithsonian Report for 1909, 225–236.

The vagaries of nitrogen in forming its various associations by which the many compounds of nitrogen found in the distillates from coal, from ammonia, and its multitude of substituted amines, to cyanogen with its numerous derivatives, result, is but one example of the multitude of complex changes and rearrangements of atoms and radical groups which occur during the process of gas making where the apparently simple method of heating the coal is employed. For numerous as the nitrogen compounds formed may be the known carbon compounds are many fold greater since they include, not only the many representatives of various known homologous groups of acyclic and

FIG. 6.



Loading tanks.

of cyclic hydrocarbons, but also many of the oxy, sulpho and nitrogen derivatives of these hydrocarbons.

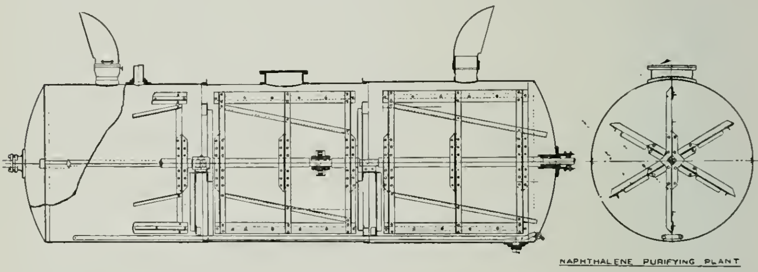
Attention has been called to the necessary variations in the composition and character of the gas which must result from the variations occurring in the composition and constitution of the coal used; the differences in the forms, proportions and character of the devices used in the carbonization of this coal; and particularly in the methods employed in the carrying out of the process, but the effects of these many differences are, if possible, more obvious in the tar, which is one result, than in the gas, which is another result of the destructive distillation, and this fact is of prime importance for consideration by the gas works manager since tar stoppages are not infrequent sources of trouble in operation which may to an extent be remedied by so conducting the distillation process, in any system, as to obtain more liquid or less highly carbonized tars.

For it is well known and has long been known that in this distillation process heavy hydrocarbons or hydrocarbon derivatives of high boiling points, which have been evolved from the coal by heat, may condense before reaching the hydraulic main and fall back upon the incandescent coal mass in the retort or upon the incandescent walls of the retort or other container, where they are cracked, depositing carbon, which appears on the walls as gas carbon, and yielding lighter and more volatile gaseous products which again pass on to mix with the other gaseous products, but bearing with them some portion of the carbon, which has not been deposited, to foul the tar.

At the time that these splitting up processes are going on, or nearly simultaneously with them, building up processes may be taking place, for it is well known that under conditions such as obtain in gas retorts or in the gas making system in practical use, acetylene and acetylene homologues, such as methyl-acetylene, polymerize to benzene, and benzene homologues, such as mesitylene, which may again be decomposed into simpler products at more elevated temperatures and which pass partly to the gas and partly, and more largely perhaps, to the tar.

It is this complex, vile looking, evil smelling, adhesive, by-product, tar, which was for long a stumbling block in the development of gas lighting. Early in the progress of the industry efforts were made to utilize it, but they proved of so little avail that when possible much of it was run off as a waste product into neighboring water courses destroying the fish, fouling the craft floating on the water and the structures bordering it, and giving rise to nuisances of a great variety of kinds. Among the unexpected results of this procedure I may recall that when in 1882, under orders from the Secretary of the Navy, I visited the Navy Yard at Brooklyn, N. Y., to investigate the cause of the corrosion of the copper sheathing of the newly fitted U. S. S. *Juniata*[6] and of other vessels which had been fitted with suits of copper at the Brooklyn yard, I found in the Wallabout considerable deposits of coal tar which had been rejected by the adjacent gas works in earlier days, and my experiments tended to show that this tar had played an important part in the corrosion which entailed considerable loss.

FIG. 8.



Naphthalene mixer.

But this coal tar which was despised and rejected by man; which was a burden to the manufacturer and a nuisance to his neighbor, has, through the researches of the chemist, become a much valued and highly considered substance, and an aid to the gas industry, which it has helped to maintain and extend, and through which the demands for cheaper gas has partly been met. Its history is filled with romance. The first English patent ever issued relative to the destructive distillation of coal was that dated August 19, 1681, and granted to J. J. Becher and Henry Serle "for a new way of making pitch and tar out of pit coal." At the outset tar was therefore to be classed as the principal product with gas and coke as by-products of the coal tar industry, but the industrial development took other courses and the order of importance was reversed until the production of pitch and tar proceeded on such a scale that, as stated, the gas makers were compelled to dispose of it at almost any hazard and in every possible way, and yet to-day through another change in industrial development this tar has become, perhaps, the most highly prized, or at least the most intellectually honored, of all the products resulting from the destructive distillation of coal.

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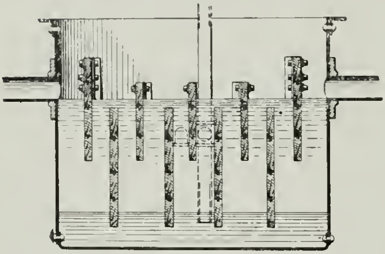
[6] Proc. U. S. Naval Institute 12, 391, 1886.

It is here that the real romance begins when studied by methods, such as those spoken of earlier in this paper as promising man information relative to the constitution of coal, and when by additional methods this blackish, viscous, forbidding appearing tar was examined it was found to be a storehouse of most interesting materials; and it has been found to be a storehouse of most fascinating possibilities and realizations.

It has been asserted that all foul smelling substances are composition of matter, and it is a fact that carbon disulphide which, notoriously, has long been condemned for its disgusting odor appears as a sweet, ethereal smelling compound when separated from its associates by the methods of purification devised by the chemists. Likewise it has been suggested that offensive looking bodies are composites. Whatever may be true of this theory in its general application it is certain that coal tar, which, in common with wood, water gas, petroleum, cotton-seed oil and other tars, of organic origin, is offensive in appearance and odor, is a product of the distillation of organic substances, and that all of these distillates are composites, and that when each of the chemically individual components of these compositions is separated from the composite mixture it appears in an agreeable condition to mankind as regards odor, or color, or as tried by other physical characteristics through which substances are differentiated or distinguished. For from coal tar there has been obtained the water white or colorless benzene and its equally colorless homologues which possess such pleasant odors and which give rise to compounds of such markedly pleasant odors that the series of hydrocarbons of which benzene is the initial member has been long since styled the aromatic series.

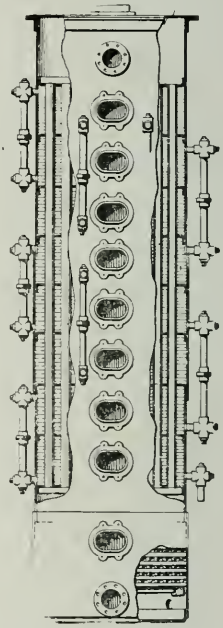
This is but the beginning of the enumeration of the hydrocarbons present in coal tar, for besides the benzene series there has been found present many of the conjugated derivatives of benzene, such as naphthalene, fluorene, phenanthrene, anthracene, and many others. Moreover there has been found present besides ammonia, nitrogen containing compounds, such as aniline, the pyridines, the picolines, the quinolines and isoquinolines and many other nitrogen containing compounds; sulphur compounds, such as thiophene and the derivative thiophenes; and hydroxy compounds, such as the phenols, and the cresols. This review embraces but a limited number of the numerous compounds which go to make up the material styled coal tar. The number and amount of each varies with the source from which the tar is obtained and the manner and means by which it is produced.

FIG. 7.



Tar separator.

FIG. 9.



Dephlegmating condenser.

No one of these separate chemical substances is to be regarded as a by-product of the gas industry, for they are usually isolated from the coal tar in other establishments than gas manufacturing establishments. They are spoken of here only that we may note the effect and influence of the gas industry on other industries, and in doing so it may be proper to recall that the substances enumerated as occurring in coal tar are not only used by themselves to produce certain useful and beneficial effects, but that they are more largely employed as the raw materials for further manufacture, and that from them we obtain not only compositions of matter such as cleansing compounds, paints, paint removers, and the like, but also many chemical compounds having most valuable properties. It is from these isolated components of coal tar that we now produce the many coloring matters, a large part of which are used as dyestuffs, such as the aniline colors, the synthetic alizarine, which has driven the natural madder dyes from the market and which has opened the area formerly devoted to the growth of the madder root to the cultivation of food crop, and synthetic indigo which is rapidly displacing the indigo produced from natural sources. Antiseptics and germicides, such as carbolic acid and the naphthols. Explosives such as picric acid and the trinitrotoluene, known as trotyl. Flavoring materials such as the methyl salycilate and vanilline. Perfumes such as geranoil and artificial musk. Febrifuges such as antipyrine, acetanilid and many other synthetic remedies. Sweeting principles such as saccharine, and photographic developers such as hydroquinone.

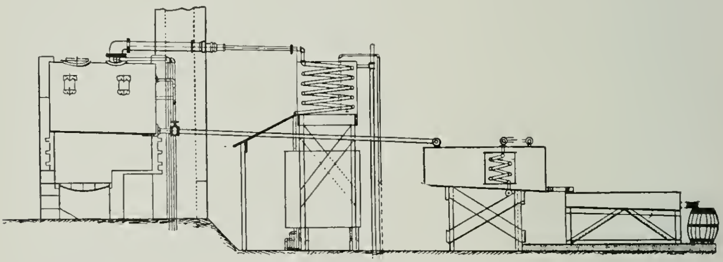
Numerous as the bodies mentioned are, they form but a very small part of the many substances which have been or may be derived from coal tar in its further manufacture, nor do they begin to exhaust the beneficent results which have followed this chemical utilization of what was formally a wasted by-product, for the coal tar dye industry has conferred a benefit of incalculable value upon bacteriology and upon all mankind by furnishing dyes which, when applied to microscopic preparations, make it possible to distinguish and recognize the germs of typhoid, cholera, tuberculosis, and other diseases; it is alleged that the industry was the principal cause of the establishment in Germany in 1877 of the imperial patent office; it is certain that the study of the constituents of coal tar and of their derivatives has created an almost new chemistry which development was largely facilitated by the ingenious speculations of August Kekulé regarding the constitution of the benzene ring advanced by him in a masterly treatise in 1865. Largely because of the insight which this theory of Kekulé gave man regarding the constitution of benzene and the possibility of obtaining from it, and its homologues, many of the chemical compounds already known and desired and many others indicated but not previously known, an enormous industry was created which within forty years from the promulgation of the theory employed more than 15,000 workmen in

Germany alone, producing products of a commercial value reaching to tens of millions of dollars and advancing the industry of mankind in a multitude of ways.

While coal gas tar has for more than a half century played a most important part in the chemical development of many countries, water gas tar which has been produced, particularly in this country, in very large quantities, has until recently been an unutilized by-product except in so far as it has been used for fuel, when mixed with breeze, under the retorts of boilers or as a source of power, in internal combustion engines, such as the Diesel engine, but through the investigations directed by Mr. W. H. Gartley, this material of which we have a most abundant supply has recently been made to yield its valuable components for use in further manufacture.

Water gas tar is a very complex mixture of a great many hydrocarbons. The principal commercial hydrocarbons are probably as follows: Benzol, toluol, xylol, naphthalene, methylanthracene, phenanthrene, and probably in the pitch, chyrsene and pycene. Water gas tar is formed in the carburetter and apparatus by the contact of the oily vapors, used in carburetting, with the highly heated checker brick. Its formation differs from that of coal tar, in that the temperature which obtains is moderate and is very exactly regulated and the time of contact is short and uniform, and furthermore, there is a high percentage of hydrogen present at the start due to the water gas which is to be carburetted. The free carbon, therefore, in water gas tar is very low compared with that in coal gas, and its composition is generally more uniform. The oil used for enriching carburetted water gas varies in character from the paraffine base oils of Pennsylvania and Ohio to the asphaltic base oils of Texas

FIG. 10.

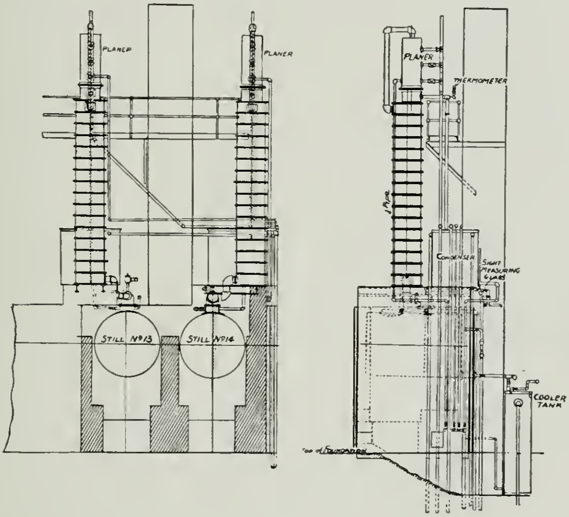


Tar still.

and California. The presence of the hydrogen in water gas as affecting the formation of the tar is shown by the increased amount of olefines and the smaller amount of tar formed, which is more complex in its nature in the case of water gas tar than the tar formed by the simple decomposition of the oil.

The general differences between water gas tar and coal tar are that water gas tar has a very low free carbon content; corresponding fractions have a slightly lower gravity; a larger fixed carbon content; absence of oxygenated compounds and a general increase in methylated derivatives, especially in the higher hydrocarbons, this confirming, in general, Schulze's theory of pyrocondensations at lower temperatures. Water gas tar varies in character somewhat according to the original character of the oil and to the method of operation of the set, particularly as regards the temperatures carried in the fixing vessels.

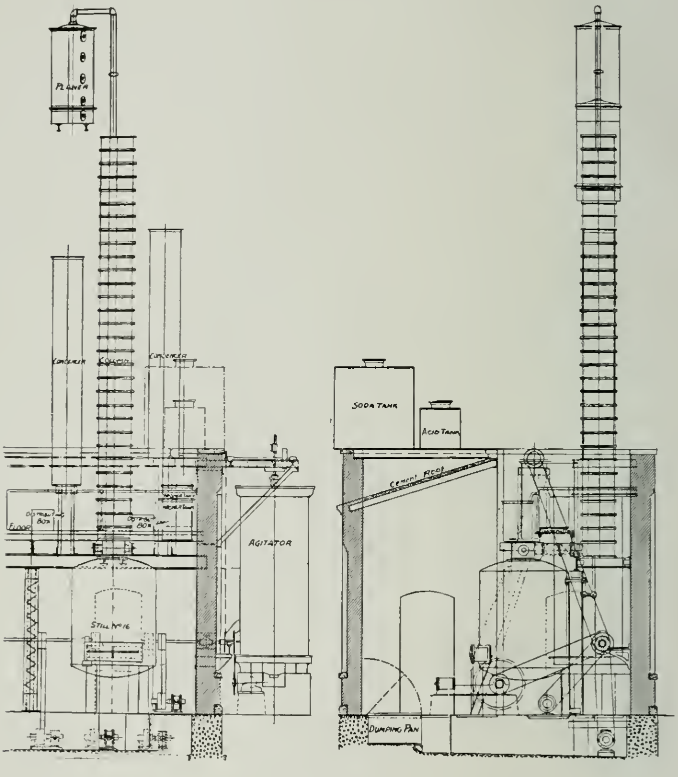
Fig. 11.



Fire column still.

The water gas tar as it leaves the apparatus exists generally in the form of vapor. This is dropped out when the temperature of the gas is reduced in the wash-box, scrubbers and condensers, and the last traces are removed in the P. & A. tar extractor. A considerable quantity of water is also condensed at the same time, and the mixture of oil and tar is separated by utilizing the differences in specific gravity. The crude tar thus separated still contains considerable amounts of water held in suspension. This is further separated by storage of the crude tar in large tanks, where in time the water separates out to such an extent that the tar will contain not over 1 or 2 per cent. of water.

FIG. 12.



Steam stills.

The crude tar is distilled in a fire still; that is, one provided with direct fire, and is cut into a number of fractions such as light oil, creosoting oil and naphthalene oil. The residue in the still is worked up then, according to the temperature of the distillation, into road compounds and pitches. The naphthalene oil fraction is chilled, and the naphthalene separated out in centrifugal machines. The light oil is washed with sulphuric acid and soda, and redistilled in stills provided with dephlegmating columns into crude benzols, toluols, etc. These are further redistilled to obtain the pure products.

The relations between tars from various sources as tested in this research are set forth in the following tables.

Comparative Ultimate Composition of Coal and Oil and Coal-Tar and Water Gas Tar.

	Coal.	Coal-tar.	Oil.	Water gas tar.
Carbon	82.47	89.21	84.28	92.70
Hydrogen	6.01	4.95	13.46	6.13
Oxygen	6.81	4.23	1.41	.69
Nitrogen	1.88	1.05	.24	.11
Sulphur	2.83	.56	trace	.37
Heating value, B.t.u's.	15353	15708	19200	17193

Comparative Distillations of Different Types of Tars.

	Horizontal.	Coke oven.	Vertical.	Water gas.
Start to 105°	0.4	1.0	0.1	1.1
Specific gravity at 25° C.	1.2039	1.1696	1.1302	1.0679
Free carbon, cold C.S.$_2$	21.16%	9.36%	5.83%	.30%
Distillation, per cent. by weight—				
105–170°	1.4	0.3	1.1	2.8
170–225°	10.8	10.0	13.9	9.0
225–270°	10.1	12.4	12.5	12.6
270–300°	4.4	4.3	4.9	10.6
300–360°	4.6	3.0	1.5	7.9
Above 360°	20.4	28.0	27.3	30.4
Coke	46.5	40.6	35.5	25.4

Comparative Distillations of Three Types of Materials.

	Asphaltic oil.	Water gas tar.	Coal tar.
Specific gravity	.9177	1.1165	1.2090
Free carbon	.22	.90	19.80

Distillation—

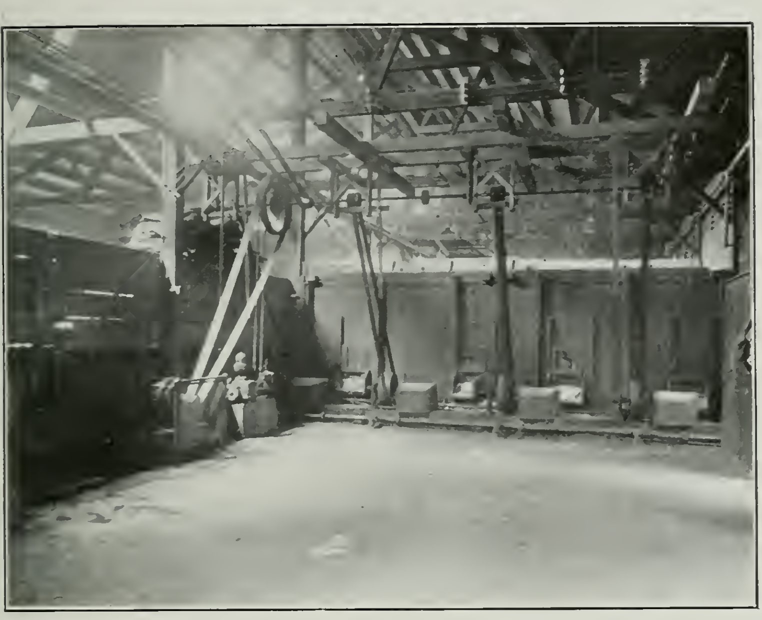
	% by wt.	Gravity.	% by wt.	Gravity.	% by wt.	Gravity.
Start–110°	.32	.9105	.29	.9550	.52	.9862
110–170°	.75	.8215	1.44	.9637	3.06	1.0095
170–235°	6.25	.8436	14.61	.9900	13.39	1.0146
235–270°	23.51	.9604	24.05	1.0188	12.78	1.0357
270–315°	48.00	.8782	15.73	1.0422	10.57	1.0785
Residue	20.27	1.1471	43.31	1.2310	58.92	1.2850

The next table shows diagrammatically the products now commercially obtained from water gas tar.

WATER GAS TAR PRODUCTS.

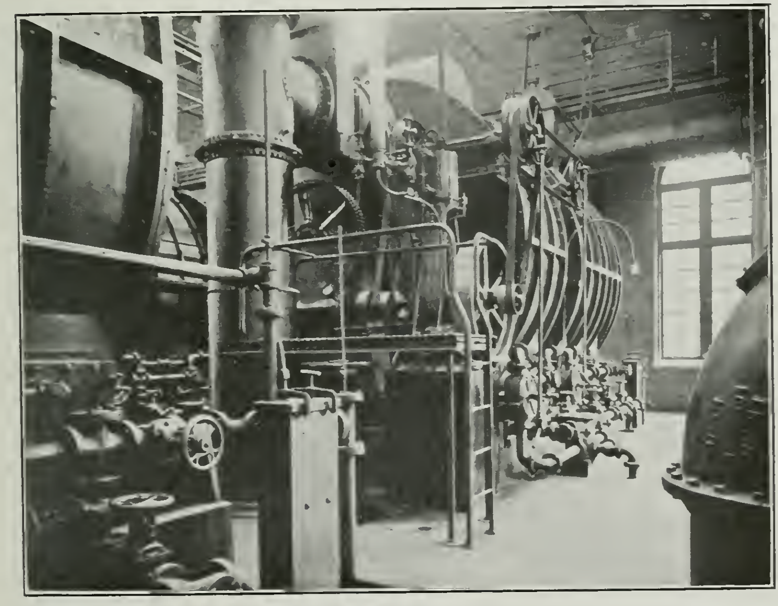
- Crude Water Gas Tar
  - Light Oil ....
    - Crude Benzol ....
      - Refined 90% Benzol.
        - C. P. Benzol.
        - Refined Special Fraction.
        - C. P. Toluol.
      - Residue ....
    - Crude Toluol ....
      - Refined Com. Toluol.
        - Refined Special Fraction.
        - C. P. Toluol.
        - Refined Solvent Naphtha.
      - Residue ....
    - Crude Solvent Naphtha ......
      - Refined Solvent Naphtha ....
      - Residue ....
    - Crude Heavy Naphtha ....
      - Refined Heavy Naphtha ....
      - Residue ....
  - Naphthalene Oil ....
    - Naphthalene Salts...
    - Dead Oil ....
  - Dead Oil ....
  - Creosoting Oil ......
  - Road Compound ....
  - Pitch ....

Fig. 13.



Copperas mixing tanks.

Fig. 14.



Cyanogen washer.

It seems a far cry from the distillation of gas from coal to the extraction of gold from its ores and yet industries as different as these two are correlated. To explain, it may be recalled that nitrogen has been found in the coal and that it appears combined in the by-products in many different ways. Among them it is found in the gas, the tar, the ammoniacal liquor, and, after the gas is purified, in the purifying material, combined with carbon to form cyanogen and cyanogen compounds, such as the ammonium salts, the thiocyanates, and others. And a large part of the metallic gold now extracted from low grade gold ores and tailings is, following the process devised by MacArthur and Forrest and modified by many others, dissolved out by aqueous solutions of the alkali cyanides which can be operated so economically that in certain localities ores containing so small a gold content as one dollar per ton can be worked to profit.

There have been many methods of cyanide recovery devised. These are described by Robine and Lenglen.[7] Among them is the Bueb process used to some extent in this country which consists briefly in scrubbing the gas, before its ammonia and sulphide is removed, with a solution of copperas whereby ammonium sulphate which remains in solution, and ferrous sulphide, which remains in suspension, are produced. The hydrogen cyanide and free ammonia in the gas now react with the ferrous sulphide giving ammonium ferrous ferrocyanide of the formula $(NH_4)_2FeFe(CN)_6$. Some of this double ferrocyanide may be converted into soluble ammonium ferrocyanide by the reagents present and to prevent this the "mud" is either boiled or made slightly acid with sulphuric acid.

In either case the insoluble double ferrocyanide is formed and the mud changes color from almost black to light yellow. The final products are an insoluble double ferrocyanide, and a solution of ammonium sulphate, which are separated from each other by filtration. The process has been found to work best at temperatures not exceeding 100° F. Under these conditions 90 to 100 per cent. of the total cyanogen is extracted. On a yield of 1¾ pounds of cyanogen per ton of coal carbonized, equivalent to about 110 grains of cyanogen per 100 cubic feet of gas the amount of copper as required theoretically is 6.3

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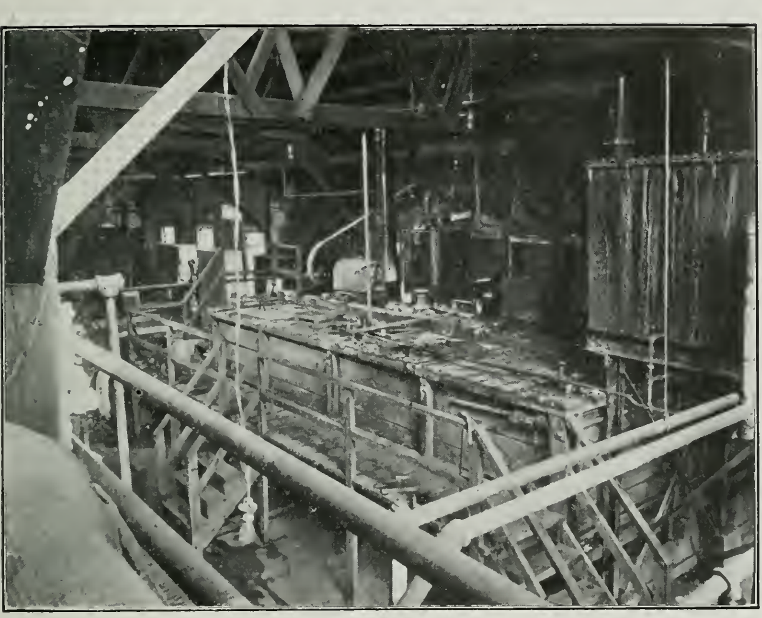
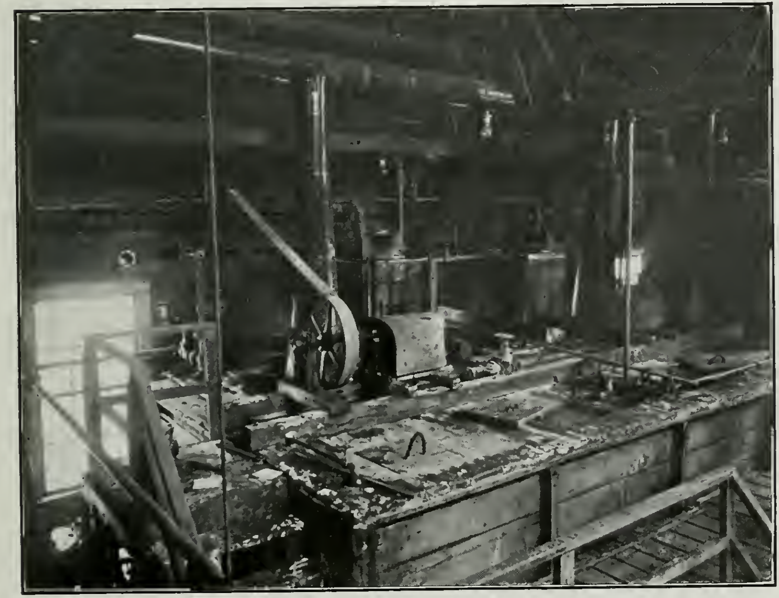
[7] "Cyanide Industry." Trans. by J. A. LeClerc, with appendix by C. E. Munroe. John Wiley & Sons, New York, 1906.

FIG. 15.



Neutralizing tanks.

FIG. 16.



Top of neutralizing tanks.

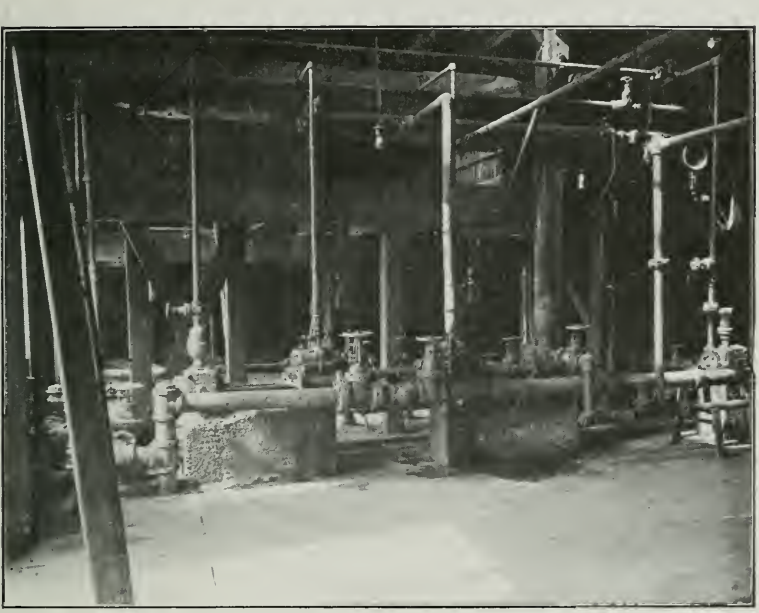
pounds and varies very little from this in practice. The ammonia absorbed in the process is equivalent to from 4 to 4.5 pounds of ammonium sulphate per ton of coal. About two-thirds of this appears as ammonium sulphate and one-third as insoluble ammonium compound in the press cake. The absorption of cyanogen by the Bueb method generally takes place in a standard washer. The gas should reach the washer freed from tar and at a temperature not over 100° F. The solution of copperas (ferrous sulphate) is run into the outlet end of the washer, where it is first converted into ferrous sulphide and ammonium sulphate. There is a tendency for the ferrous sulphide to adhere to and build up on the exposed surface. This would soon clog up the bundles in a standard washer, and for this reason the bundles in the last tray are replaced by large discs attached to the shaft and spaced about 3 inches apart. But even these gradually clog up and must be cleaned at times.

A device which kept the liquid in this chamber violently agitated would probably be preferable. In the original method of operating these washers the material was pumped forward from tray to tray whenever the first tray was saturated. This involved a great deal of pumping and it has been found that operating the washers on the same principle as an ammonia washer simplified the operation. The material in the inlet tray is tested from time to time by drawing off a small sample and acidifying with sulphuric acid. After stirring well a drop of this mud is put on a piece of white filter paper. Near it is put a drop of dilute ferric chloride solution so that the liquid from the two drops as they spread out on the paper will come together. A blue color occurring at the point where the drops meet is a sign that the mud contains an excess of ferrocyanide over iron and is therefore ready to be drawn off. If the material is saturated a slow stream of copperas solution is run into the outlet end of the washer. This forces the material in the different trays forward and the saturated acid overflows from the first tray. The copperas solution is kept running until the material in the first tray shows that it is no longer saturated.

In Germany the mud as it comes from the washers is generally sold to chemical works. At the Astoria plant of the Consolidated Gas Co. of New York mud is pumped into lead lined tanks heated to about 200° F. and acidified with sulphuric acid.

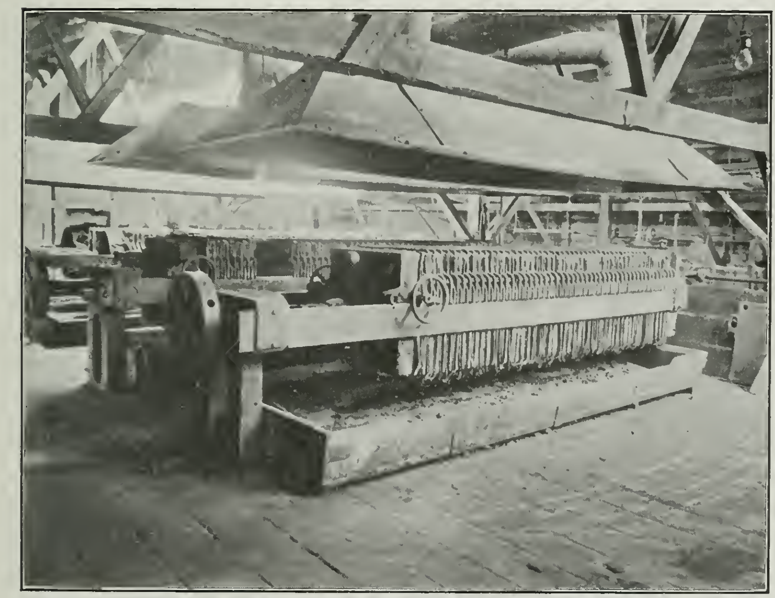
The addition of acid changes the color of the mud to light

FIG. 17.



High-pressure pumps.

FIG. 18.



Filter press ready for filling.

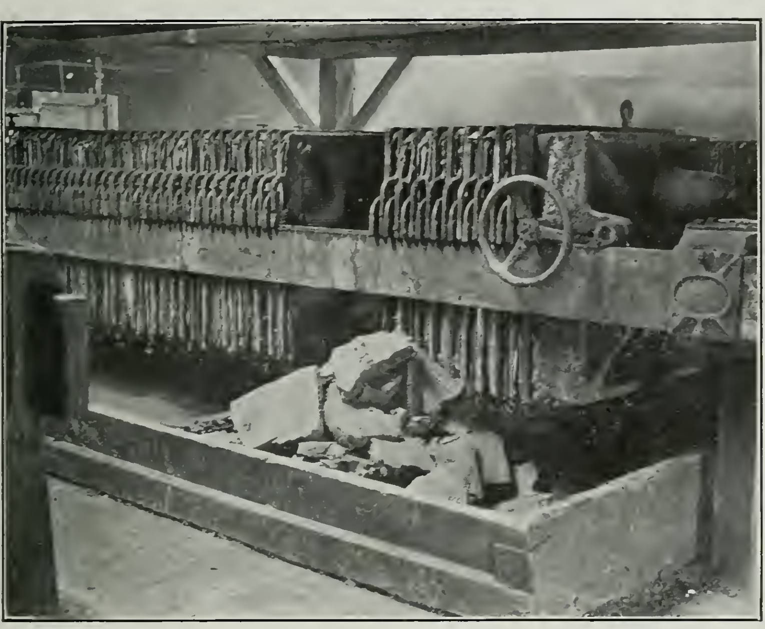
yellow. During this operation large quantities of hydrogen sulphide are set free and in order that this does not escape into the room the tanks are fitted with vent pipes connected to a fan which discharge the gases out of the building. Enough acid is used so that the material is slightly acid to litmus. The mud is again tested for soluble ferrocyanide with ferric chloride solution on a piece of white filter paper and if the blue color appears ferrous sulphate solution is added, a little at a time, until upon testing the blue color no longer appears. This converts all the cyanogen into an insoluble form.

The mud now consists of insoluble double ferrocyanide of ammonium and iron and a solution of ammonium sulphate with a little ferrous sulphate and very little free acid. This is pumped into filter presses (Fig. 18). After the press is full hot water is pumped through in order to wash as much as possible of the ammonium sulphate.

The wash water, which is a very dilute solution of ammonium sulphate, is used for making up the copperas solution. It is very difficult to wash out the ammonium sulphate. The best results are obtained by finishing the pressing with mud made by stirring up some of the finished press-cake with water until it disintegrates. The presses are about two-thirds filled with the neutralized mud from the washers and then finished with the mud made from the finished cake. In this way the gravity of the liquid coming from the presses is brought down from 8–10° Baumé to 1–2° before washing with water.

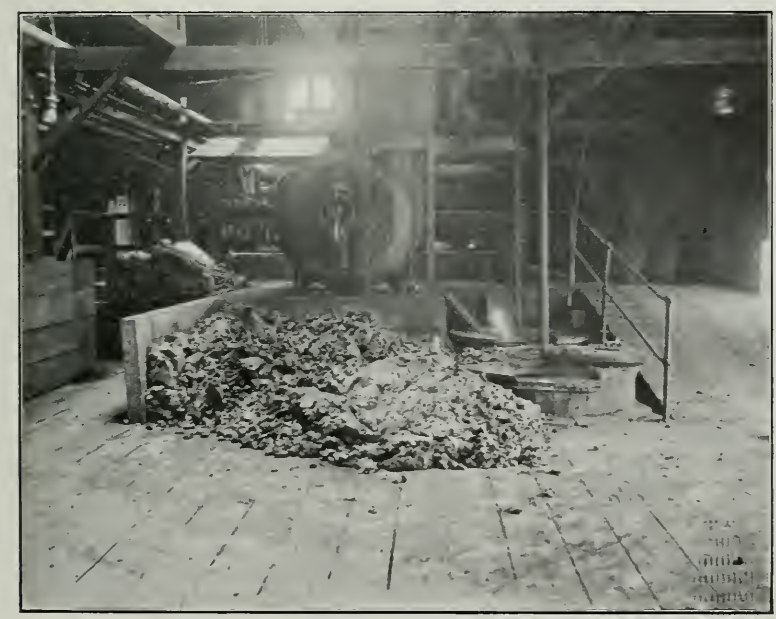
The solution of ammonium sulphate which runs from the filter presses is neutralized with ammonia. For this purpose some of the mud as it comes from the washers is boiled and the gases, principally ammonia and hydrogen sulphide, pass into the ammonium sulphate liquor from the presses. This not only neutralizes the free acid but also precipitates the small amount of iron present. This is necessary to avoid discoloration of the sulphate. The neutralized liquor is allowed to settle and the clear solution evaporated in lead lined pans. This solution contains approximately one pound of ammonium sulphate per gallon. The sulphate separates out on evaporation and is dried in a rotary drier (Fig. 24) by means of a current of air from a small blower heated by passing over steam radiators before passing through the drier. About 2.5 to 3 pounds of sulphate are produced per ton of coal carbonized.

FIG 19.



Filter press partly opened and dumped.

FIG. 20.



Pile of press-cakes.

The cyanogen cake from the filter presses has approximately the following composition:

	Per cent.
Water	50 to 40
Cyanogen	22 to 28
Ammonia	5.3 to 7

About 6 pounds of press-cake are produced per ton of coal carbonized. When it first comes from the presses it is yellow in color, but on contact with air it rapidly turns deep blue to oxidation. It is sold to chemical works to be converted into sodium or potassium ferrocyanide. This is done by first distilling with lime which drives off the ammonia and forms calcium ferrocyanide. The solution of calcium ferrocyanide is filtered from the residue of iron hydroxide and is then treated with sodium or potassium carbonate, forming the corresponding ferrocyanide and calcium carbonate which settles out. The clear solution is then concentrated and the ferrocyanide crystallized.

Through the courtesy of Mr. Walter R. Addicks I am able to exhibit the following pictures of the cyanide recovery apparatus used in a gas works in this country.

No. 13—Shows tops of underground copperas mixing tanks with motor driven stirrers; copperas bins at the rear. Copperas solution is forced over to the cyanogen washers by steam pump on the left.

No. 14—Shows cyanogen washer which received the copperas solution from tanks shown in No. 13. After the copperas solution has extracted the CN from the gas it is returned to the factory in the form of cyanogen mud and stored in underground tanks under the filter press platform until ready to be worked up.

Nos. 15 and 16—Top of neutralizing tanks where the cyanogen mud is neutralized with sulphuric acid.

No. 17—Shows two of the five high pressure pumps which pump the mud from the neutralizing tanks through the filter presses.

No. 18—Shows filter press closed ready for filling.

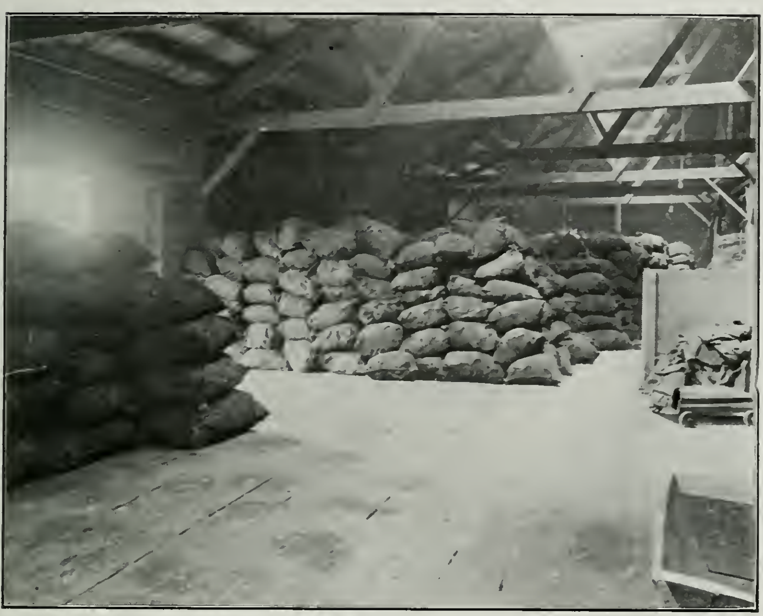
No. 19—Shows filter press open and partly dumped; the press-cake is visible in the foreground.

No. 20—Shows pile of press-cake.

No. 21—Shows cyanogen press-cake bagged, ready for shipment.

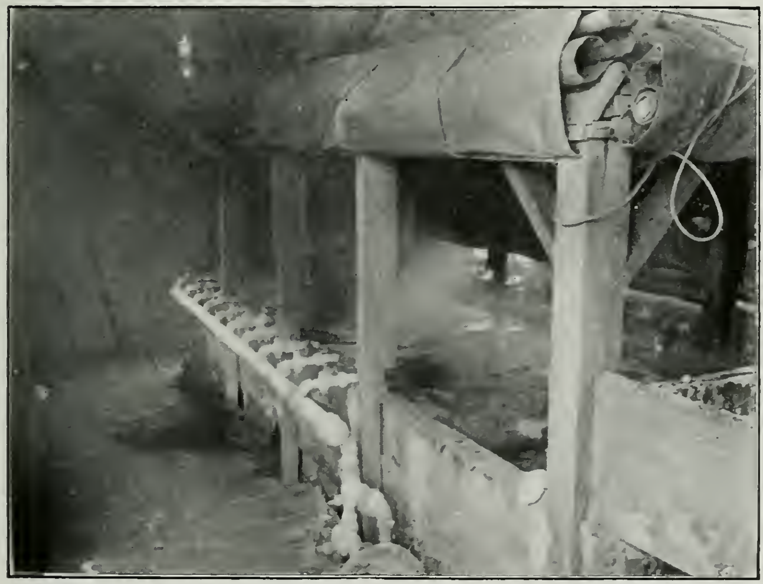
No. 22—View of lead lined evaporating pan for sulphate

FIG. 21.



Cyanogen press-cake ready for shipment.

FIG. 22.



Evaporating pan.

liquor. Note steam header to the left, which is connected to lead pipe coils in bottom of pan.

No. 23—Shows ends of sulphate evaporating pans with piles of sulphate crystals on drain-boards.

No. 24—Shows rotary sulphate dryer with pile of sulphate under discharge end to left, and bags of sulphate in the foreground.

Unfortunately the demand for cyanides is not yet sufficiently large to warrant the cyanide recovery process being pushed very far.

Another by-product which warrants further consideration is the spent oxide. Material rich in sulphur has been burnt in acid chambers and it has been proposed for use in copperas making. Two sulphur recovery processes which have been demonstrated as feasible and operative in the laboratory are now being tested on a commercial scale in the factories, Burkheiser's recovery process being operated in connection with the Flemalle Grande coke ovens near Liege, Belgium, while Walther Feld's rival process is being employed at the gas works in Konigsberg, Germany. Both aim to produce ammonium sulphate from the ammonium compounds in the gas liquor and the sulphur compounds obtained from the coal. Feld's process is of special interest to the theoretical chemist in that the formation of the commercial product sought and the saving of the useful matter accomplished is effected through the aid of the tetrathionates and the controlling under manufacturing conditions of the reactions through which they are formed and those into which they will enter.

It may perhaps be admissible for me in closing to refer to a scheme for gas making at the coal mine which has interested me much for a long time. I perhaps cannot better present the matter than by quoting from an address made to the American Institute of Chemical Engineers in 1909.[8]

"I have long looked upon our present custom of transporting coal long distances to be converted into gas as uneconomic, for a not inconsiderable quantity of coal is burned to provide the energy with which to haul this coal. Not only that but, since the gas constitutes but a very small percentage by weight of the coal, there is a considerable waste in hauling the coke, with its

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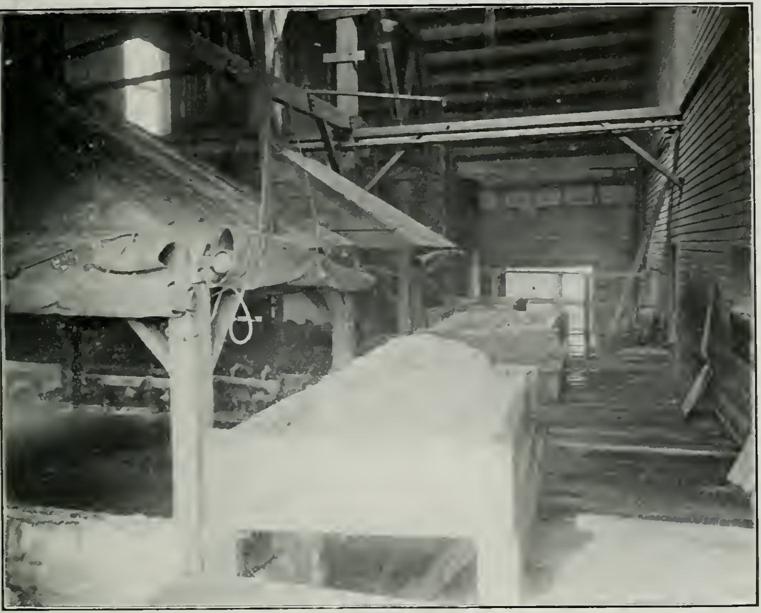
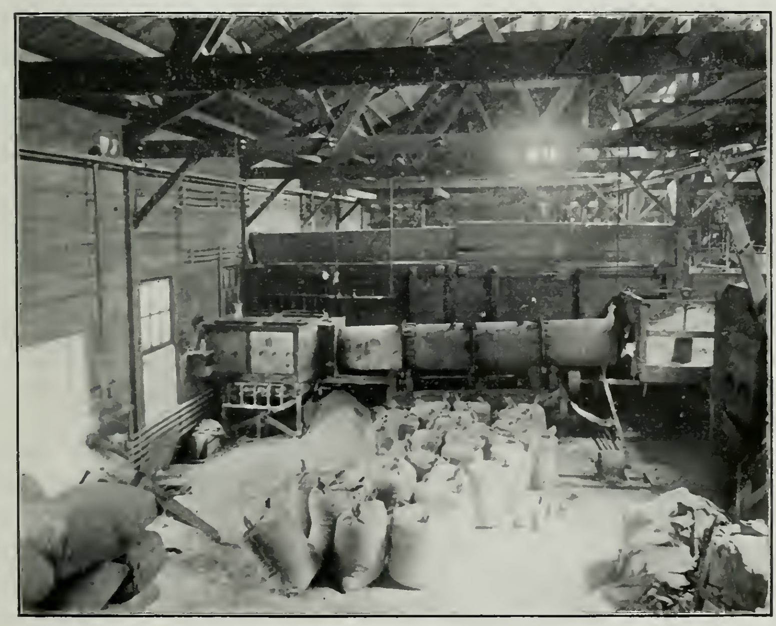
[8] Trans. Am. Inst. Chem. Eng., 2, 100, 1909.

FIG. 23.



Sulphate evaporating pans.

FIG. 24.



Rotary sulphate dryer.

ash, and the by-products. Further, to provide for emergencies, large stocks of coal must be accumulated in advance at the gas works, and as coal, particularly gas coal, begins to deteriorate as soon as it is removed from the mine, there is a very considerable loss going on all the time from this cause. Further, as the by-products or residuals are now purchased in the crude states in relatively small quantities at the different gas works, a large part of their value is consumed in collecting and transporting them to central refineries.

"By producing the gas at the mine and shipping it by pipe line the cost of haulage of the coke, with its ash, and crude by-products is saved. The wastage of coal by weathering is saved. The cost of collection and transportation of the crude residuals is saved. Such coke as is not needed for industrial purposes can be converted in producers into gas which, by means of internal-combustion engines, can be used in generating electricity for distribution, and the ash from this coal can be put into the mine for use as a filler in place of coal.

"It is evident that gas can, under these circumstances, be made and delivered at a much less cost than is the case at present, though it may be necessary after long travel to enrich it near the point of consumption. Furthermore, the valuable areas now occupied by gas plants in our cities can be given up to more concentrated industries and cheap country lands be substituted for them."

The pertinency of this proposed scheme to the topic given me for consideration lies in the improved opportunity which this plan would afford for the utilization of the by-products, and I foresee that should this plan of gas generation at the mine ever be realized there would grow up about the gas generating plant a large number of industries based upon the utilization and further manufacture of the by-products, and that they would be greatly fostered, as would many other industries, by the very cheap gas, which could, under these circumstances, be produced for use as a source of heat, power or light, and which could be so cheaply produced as to enter, on the spot, into competition with water power as a source of electric energy. It is of interest to note that Sir William Ramsey has recently given this suggestion of carrying on the manufacture of gas at the coal mine his endorsement.

RECENT DEVELOPMENT OF THE LOCOMOTIVE.[1]

BY

GEORGE R. HENDERSON,
Consulting Engineer, The Baldwin Locomotive Works, Philadelphia.

SIZE AND POWER.

Ten or twelve years ago the steam locomotive had assumed such proportions that it was thought by many engineers that the limits of size and capacity had been practically reached. The increase in weight had been going on steadily for years, but with comparatively few advances that, at a single bound, were remarkably in excess of what had previously been done. About this time, however, a number of circumstances occurred which made it absolutely imperative that more powerful locomotives be obtained, and these last ten years have produced different reasons for increasing the power of the locomotive, treading fast one upon the other.

The advent of large-capacity freight cars has resulted in a train that could be more easily handled with a large tonnage than it could be in the old cars of less capacity, as the train length is shorter and the number of cars in the train considerably diminished for a given tonnage, which is a very important factor in connection with the proper operation of the brakes when descending grades. Instead of cars of 30 tons capacity, which were the common maximum a decade since, 50-ton cars are now very plentiful, and even cars of 75 or 80 ton's carrying capacity are being seriously considered. This means that for a train of the same number of cars double the tonnage can be hauled and a more powerful locomotive can be economically used.

The introduction of steel passenger equipment, with a view to eliminating many of the horrors of fire and collision, also calls for more powerful locomotives, as the weight of these cars has been very considerably increased. In olden times a 60-ton car was considered a very heavy vehicle, but nowadays 75 tons is not at all abnormal, and a weight of 90 tons has been reached.

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[1] Presented at the Stated Meeting held Wednesday, April 17, 1912.

The agitation for increase in wages of all men connected with the transportation department of railroads has been more or less generally successful, and in order to offset, to some extent, these increased expenditures, reduction in operating expense has been necessary. This is brought about very largely by the increased capacity of the locomotive. As an example of what can be done in this line, some years ago a road with which the writer was connected found, by the purchase of some passenger locomotives of considerably greater power than heretofore used, that each of these engines in the first year during which they were operated saved $5,000 in reducing the expense incidental to double-heading trains and running two sections, where the necessary cars could be handled by one of the new engines.

The increase in traffic due to the natural increase in population, which has for the United States amounted to 20 per cent. in the last ten years, has in many cases called for either double-tracking, large additions for side tracks, or other provisions for handling an increased movement of tonnage over and above what could be arranged with the old facilities. With an increase in the power of the engine it is possible not only to handle tonnage more cheaply, but to handle a larger amount without any additional efforts in the way of dispatching or interference with other trains; for instance, if we could double the train load, we could practically move twice the amount of tonnage without increasing the number of meet orders or delaying trains in the opposite direction. On this account alone the large locomotive has been invaluable in enabling the companies to increase very greatly their tonnage without having to make large expenditures for improvement in tracking facilities, greater number of sidings, extra track, etc., and this has been no small part of the burden removed, although we do not hear as much said about this part of the operating problem as some of the others which we have mentioned.

The more recent decision of the Interstate Commerce Commission that the railroads should economize instead of increasing their rates calls for an additional effort in this line, and these cumulative experiences, coming closely one upon the other, within the past decade have brought about a locomotive of size and power which was not even dreamed of ten years ago.

The electric locomotive has made its appearance and has done very good work in certain localities, and in order to compete with such an engine, which has the output of a large stationary power-house behind it, the steam locomotive has had to increase its capability for exerting power. For years the clearance or height and width possible for locomotives, owing to the outlines of tunnels, heights of bridges, proximity of station platforms, buildings, etc., has prevented any considerable increase in these two directions, so that the remaining dimension, viz., that of length, was the one direction in which increases could be made. This has brought about, naturally, engines of long wheel base with long boilers, and, while a few years ago tubes of 16 feet length were considered as quite long enough for good design, we now find them extended to as much as 25 feet, and the end is probably not yet. Of course, these increases in size mean increase in weight, which, while it is a natural consequence of the increase in power, is also necessary to provide sufficient adhesion to make use of this increase in power. This, however, means necessity for heavier track and bridges, and, in order to reduce the load on track and bridges as much as possible, the extension of this weight into increased length has helped to keep down the weight per lineal foot. This however, is increasing, as, while a few years ago 25 tons was thought to be a very large weight on one pair of drivers, 30 tons is now very frequently considered, and is, in fact, already exceeded in a few cases.

The question of longer boilers and longer engines leads us to a good many complications which have heretofore been avoided. While boiler flues have been used up to 25 feet in length, this is about the limit at which the mills are able to roll them, and besides, it is considered wise not to increase the lengths too greatly without having experience of gradual extensions. The new lengths of locomotives in many cases require, for structural reasons, if nothing else, a barrel as great as 53 feet, and, in order to fill up this space, there have been various means adopted to supplement the length of the flues. Combustion chambers extending from the fire-box forward, a distance of 5 or 6 feet, have been introduced, and the amount of boiler has been utilized for feed-water heaters, reheaters, superheaters, and other devices, all of which tend toward economical operation and make good use of the extra length of boiler shell. These different devices will be referred to more in detail later on, but the reasons for their existence and for having space to apply them, which we did not have some years ago, should be considered at the present time.

The lengthening of the boiler and the engine means that flexible wheel bases must be introduced. The favorite type of long, rigid wheel base engine has generally been the consolidation, consisting of one pair of truck wheels and four pairs of driving wheels; to this, later on, a trailing truck was added, giving us the 2–8–2, or Mikado type of engine. There were several reasons for the introduction of this type; probably the first one was to provide an engine which could be backed around curves and switches as easily as run forward. Consolidation engines have been in the past very largely used as helper locomotives, and, after helping a train up a mountain for ten or twenty miles, it was often desirable to back them down hill to be ready for the next ascent. If the road was crooked, derailments were likely to occur when having only a driving wheel to negotiate curves. The trailing truck, therefore, was originally introduced to enable these engines to operate with equal satisfaction around sharp curves in either a forward or backward direction. The construction of boiler was kept very similar to the Consolidation engine; that is, the fire-box was above the rear drivers and the rear truck was purely for guiding purposes.

With the desire for additional heating surface requisite for maintaining higher speeds, it was found that advantage could be taken of the trailing truck to bring the fire-box entirely back of the drivers and thereby make it deeper, as the truck wheel was so much lower than the drivers. This gave longer tubes and a better fire-box for the proper combustion of fuel, and the increase in fire-box volume and heating surface has been considered so essential that nowadays the Mikado engine is used for road service, principally on account of the large boiler capacity which can be obtained thereby.

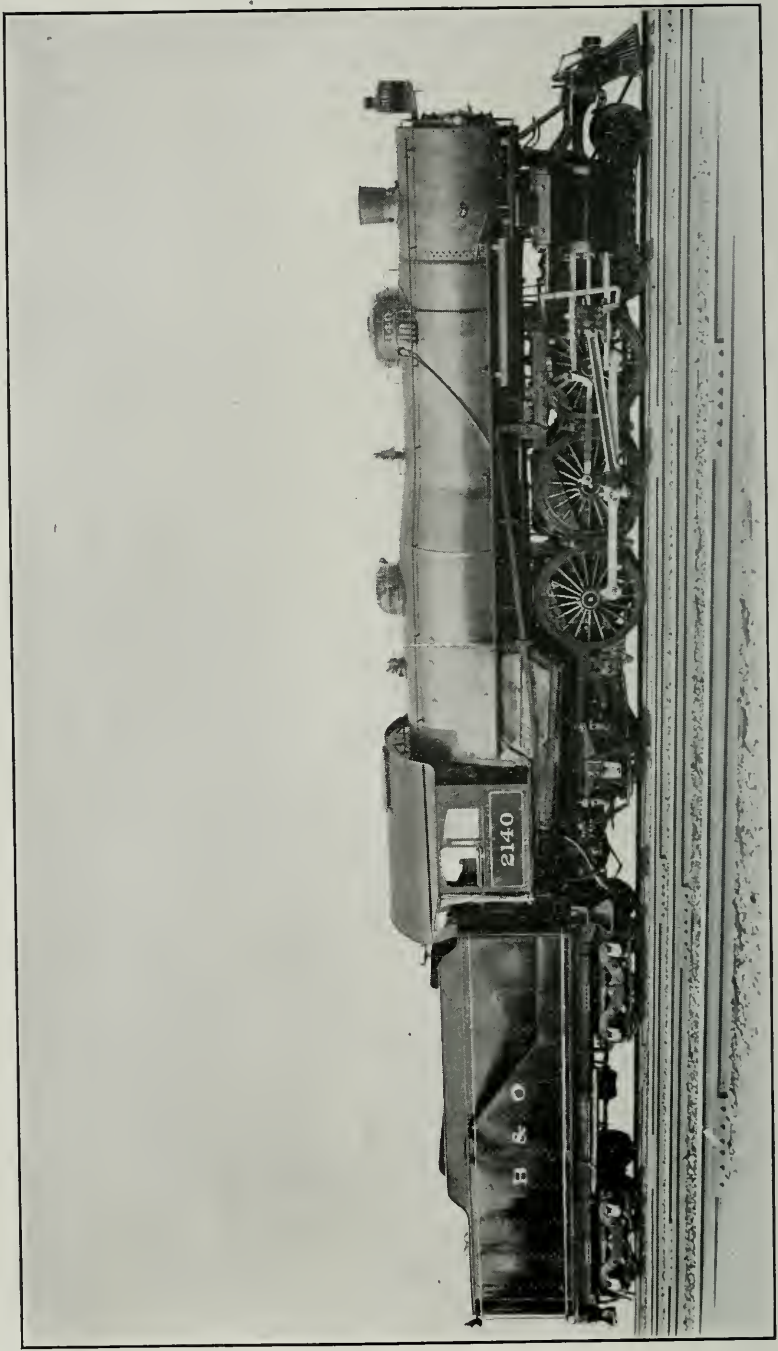
In the same way that the Consolidation locomotive was developed into the Mikado type, the Pacific locomotive was the outcome of the ten-wheel engine. In the olden times the ten-wheel engine was built with a deep fire-box between the frames and between the middle and rear driving axles, but, with the increase in dimensions necessary for modern locomotives, this space was too much restricted and the fire-box was raised entirely above the rear drivers. For the low wheels in freight service this answered well enough, but when it came to passenger engines with wheels from 70 inches to 80 inches in diameter the boiler was raised very high and there was little depth of fire-box possible. The addition of the trailing truck to this type of engine, therefore, allowed a deep fire-box and also a wide one by extending the boiler backwards until the fire-box was entirely in the rear of the driving wheels. This is illustrated by Fig. 1.

The Pacific type of locomotive may also be, in a measure, considered the logical development of the Atlantic type of engine, which first made its appearance about fifteen years ago. The original engine of this wheel arrangement was constructed for the Atlantic Coast Line in 1895, and was simply a ten-wheel engine with the rear driver changed to a trailing wheel in order to give room for a deep and longer fire-box, which could not be obtained with the regular high driving axle at the rear. The particular object to be obtained in this case was an increase in steaming power to haul at greater speed heavy trains which were needed for carrying the passenger traffic at that time. This engine, it will be noted, was not provided with a trailing truck, but the trailing wheels were simply placed in pedestals and located at about the same place where the third pair of drivers would have been in a ten-wheel type of locomotive. In this case it was not a question of adhesion so much as the possibilities of sustained horsepower at high speeds, and, as the tractive force of a locomotive always diminishes as the speed increases, the maximum adhesion is never used, except in starting and at very slow speeds.

The Pacific type of locomotive has become particularly popular for high-speed freight and heavy passenger service, and might now almost be considered the standard type of passenger locomotive used in this country for heavy trains at high speeds. For steep grades the Mikado type of engine has been used very successfully in passenger service, particularly on the Union Pacific Railroad, by making the driving wheels sufficiently large for the purpose intended and keeping the fire-box over the rear truck, as shown by Fig. 2.

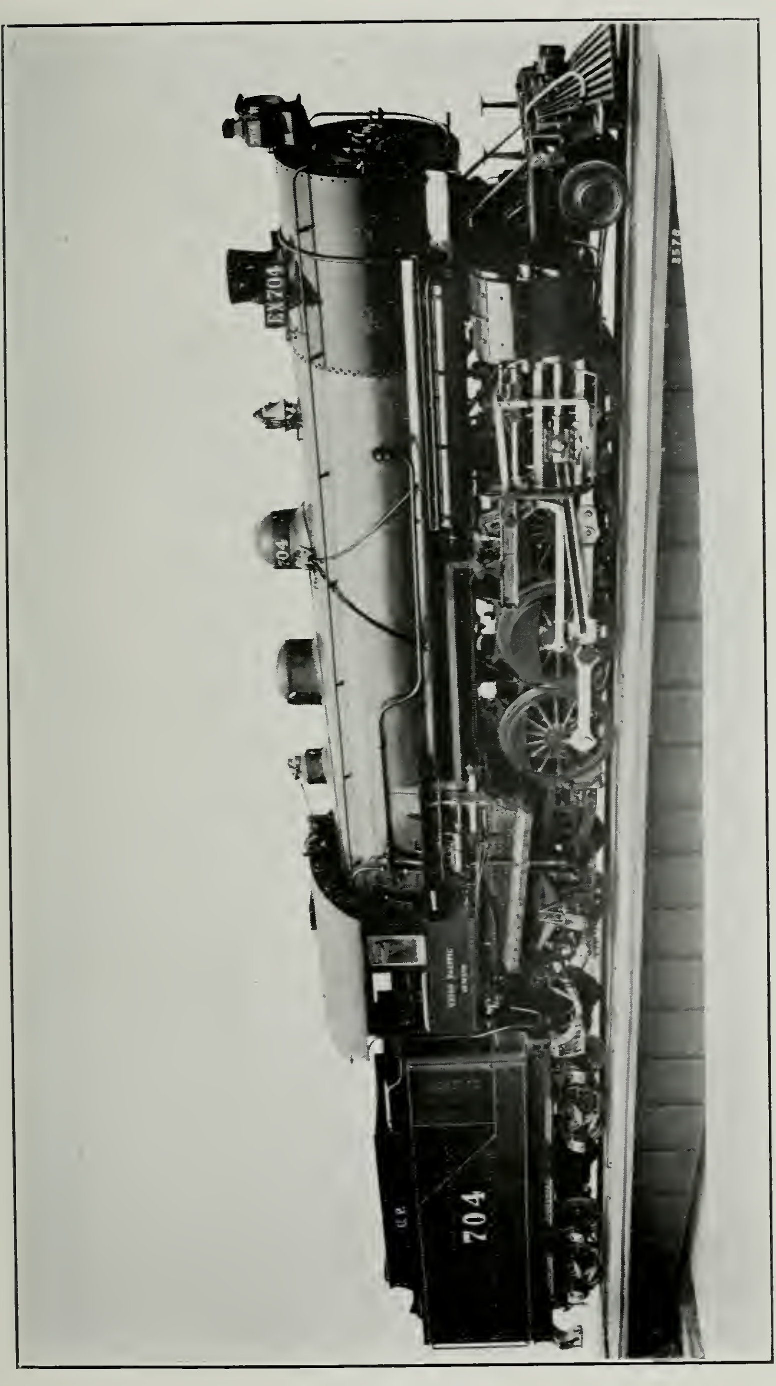
It has been a general axiom in locomotive construction that the diameter of the driving wheels in inches should be as great

Fig. 1.



Pacific type locomotive.

FIG. 2.



Mikado type passenger locomotive.

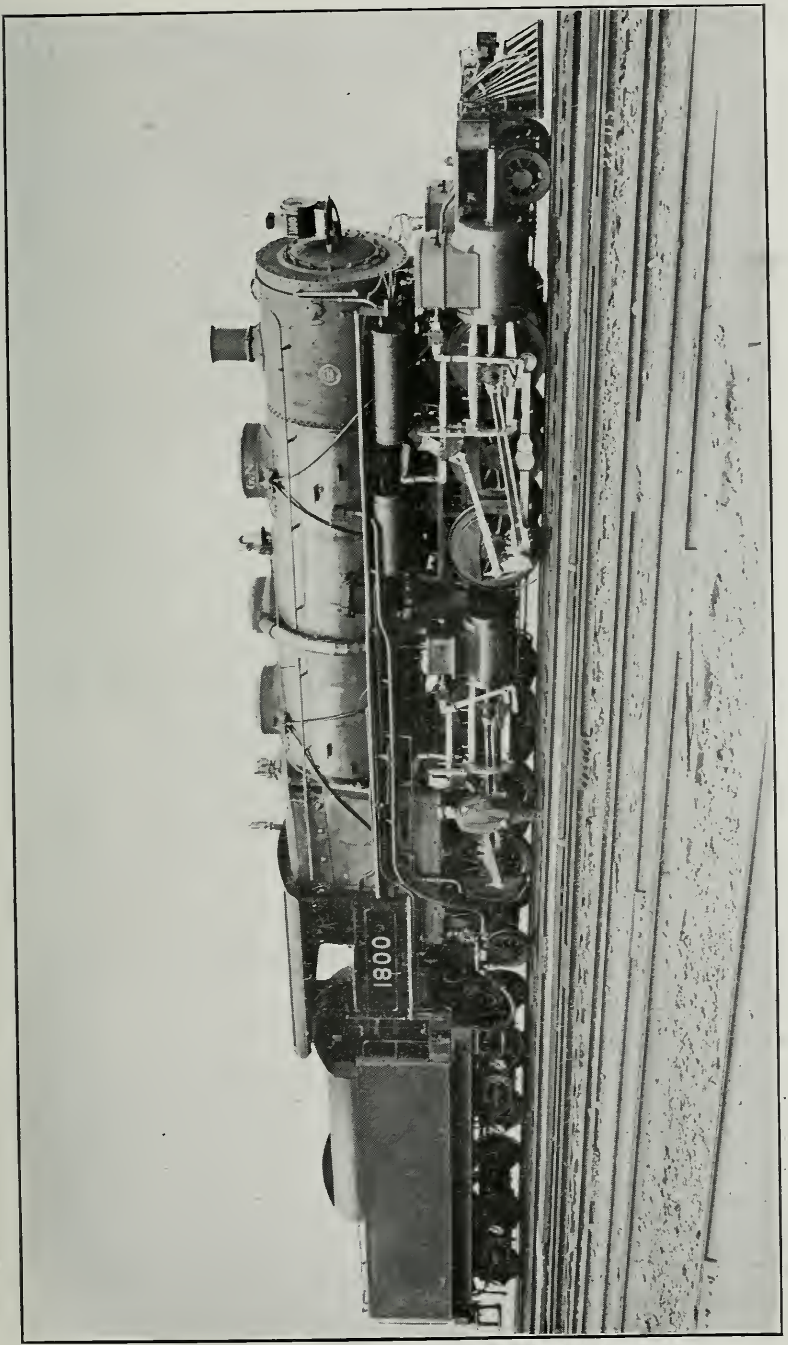
as the maximum speed in miles per hour at which the engine is intended to run, this resulting in a speed rotation of 336 revolutions per minute when the speed above mentioned is attained.

In 1903 the Santa Fe type of engine, which is a 2–10–2 locomotive, was introduced, and which was really a Mikado engine with an extra pair of drivers inserted in the rigid wheel base. While it is the practice in this country to use flanged tires on all the drivers of Consolidation locomotives and those having a less number of driving wheels, yet when it came to the five pairs of drivers the flange was omitted from the middle wheel. It had been the custom to use bald tires on Consolidation locomotives, but experience later demonstrated that by placing the tires of the front and back wheels closer together than the middle wheels the tire wear was more uniformly distributed over the different wheels and there was no difficulty in passing curves of fairly sharp radius. At the present time a locomotive of the 2–10–2 type with 30-inch by 32-inch cylinders is being built, reviving the Santa Fe type of nine years ago. These latter engines will be used on the Chicago, Burlington and Quincy Railroad.

It seems, however, as if this was the greatest aggregation of driving wheels that could be used in a rigid wheel base, and when it is desired to use more than ten driving wheels it is necessary to go into the Articulated type of locomotive. The particular style most used in this country at the present time is termed the "Mallet," as it was originally proposed by M. A. Mallet, of Paris. In this device there are four cylinders, each pair operating a set of driving wheels in individual frames, the two sets being connected together by a hinged joint. This enables an engine with six, eight, or even ten pairs of driving wheels to pass curves with no more resistance than engines heretofore employed.

There have been two ways of connecting the boiler to such engines and frames, the original method being to have the boiler with a rigid shell firmly attached to the rear engine and to allow the front, or low pressure section, to oscillate and slide transversely under the front end of the boiler, connection being made by means of flexible steam pipes (see Fig. 3). Sometimes, however, the overhang of the boiler is too great on sharp curves, and then recourse is had to the flexible boiler, or one with the

FIG. 3.



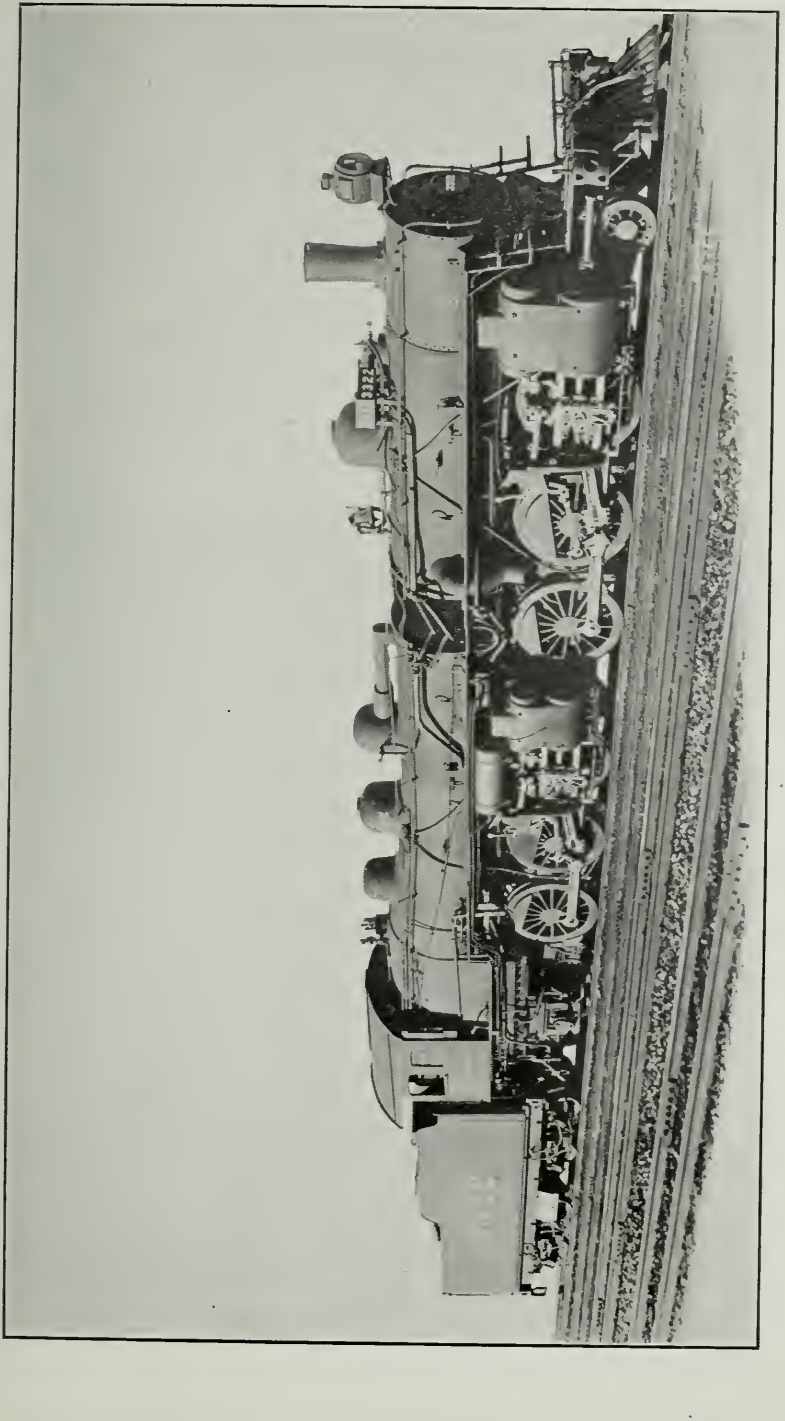
Mallet locomotive.

"accordion" joint, as it is called. In this case both sections of the boiler are secured rigidly to their respective frames, but the accordion joint allows the boiler to bend when passing curves. This is illustrated by Figs. 4 and 5, the latter showing an enlarged view of the joint in the boiler.

In both these types of Mallet locomotives the rear wheels are operated by high-pressure cylinders receiving steam direct from the boiler, and this steam, after passing the high-pressure cylinders, goes through an intermediate receiver into the low-pressure cylinders, and finally to the exhaust. The various heaters of which we have above spoken are utilized in some cases, first, to superheat the steam before passing to the high-pressure cylinders, and, secondly, to reheat the steam in its passage from the high- to the low-pressure cylinders. The feed-water heater at the front end has been used to abstract heat from the gases during their last passage in the boiler so as to increase the temperature of the water and bring it practically up to a boiling point (at boiler pressure) before being delivered into the boiler proper. These various combinations of heaters and compound cylinders, of course, very considerably reduce the fuel consumption, which is an extremely important factor, now that the boilers have assumed such enormous size. It has been found by experience that an ordinary fireman cannot, as a regular performance, put in the fire-box more than from five to six thousand pounds of coal an hour, and, while for a short period some good men can exceed this rate, yet, ordinarily, it is unwise to expect him to handle more than this amount of fuel. The compound principle generally effects an economy of about 20 per cent., and as superheaters, reheaters, feed-water heaters, etc., may give as much more, it is plain that these devices have enabled us to get more power out of a locomotive fired by a single fireman than would be possible with ordinary simple expansion engines without the devices referred to.

The limit of physical endurance of the fireman has recently been recognized as the actual limiting factor in the development of power by a large locomotive, as it is found that locomotives with increasing size do not develop ordinarily horsepower in proportion to that size. Repeated tests of locomotives on testing plants and also in actual service indicate that one horsepower can ordinarily be obtained by from two or three square feet of

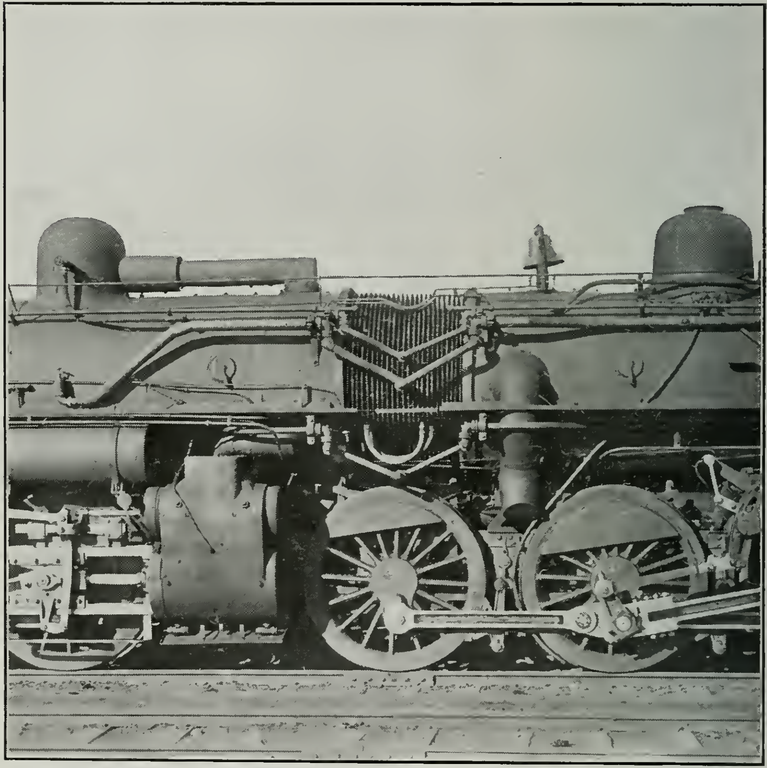
FIG. 4.



Flexible boiler Mallet locomotive.

heating surface, the former value being susceptible of attainment with compound locomotives and those equipped with a special economical device, while the latter figure applies to the ordinary saturated locomotive without the devices above mentioned. Under ordinary conditions the saturated steam locomotive will develop a horsepower with about four to five pounds of coal per hour, and for 1,000 horsepower there would be very nearly as much coal required as could be placed by an ordinary fireman. With compound engines, superheaters, etc., of course, the capacity of the fireman in horsepower can be very considerably increased, as above noted, but it is a fact that even locomotives

FIG 5.



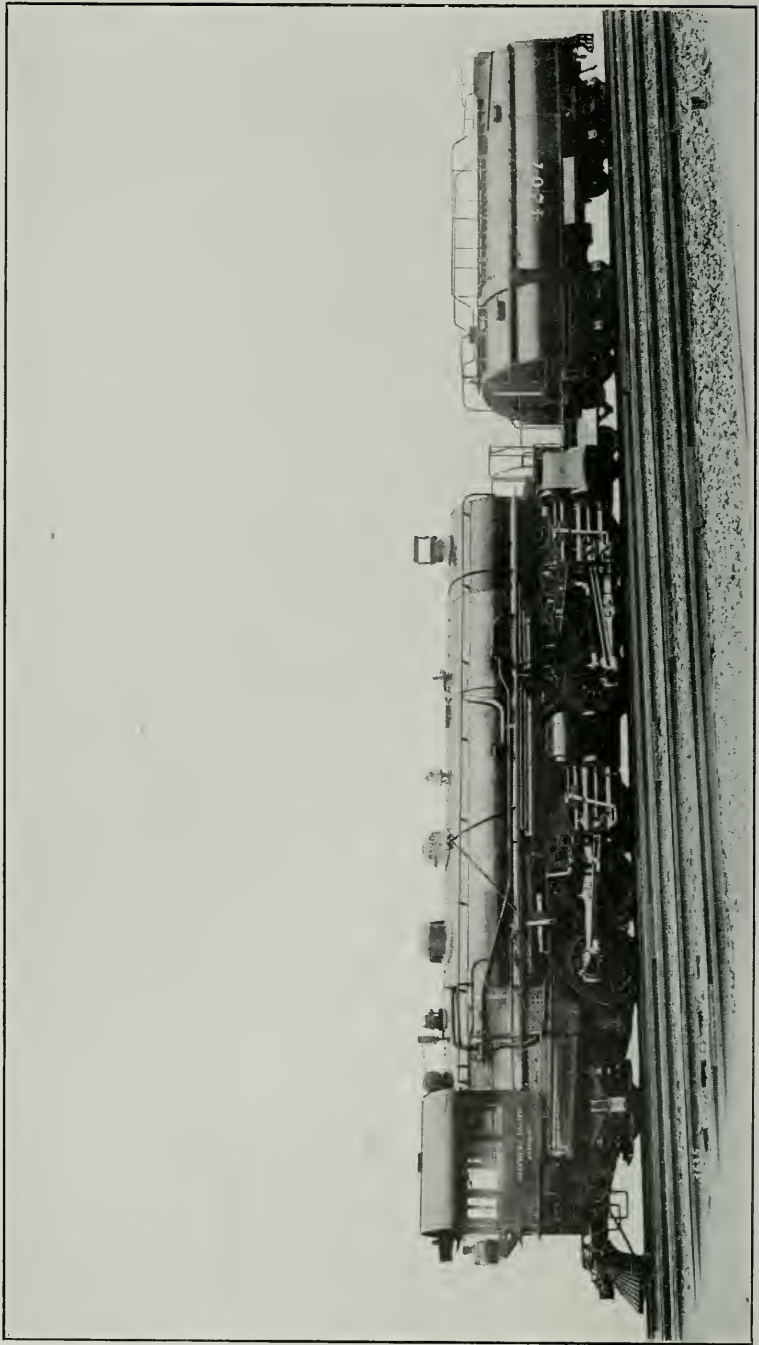
" Accordion joint."

with 5,000 or 6,000 square feet of heating surface often deliver only about 1,200 or 1,500 horsepower. This limitation of the steaming capacity, due to the human element of the fireman, has brought about the investigation and introduction of mechanical stokers, of which more will be said anon, but it is here mentioned in order to account for the extreme sizes of locomotives that have been proposed, as well as some actually under construction. Of course, the same limitations do not apply to locomotives which burn oil, as there is no difficulty in getting sufficient oil in the fire-box for practically any reasonable rate of combustion, and some of the largest engines heretofore built have been arranged to burn liquid fuel. This is notably true of the southwestern part of this country, where the oil fields in Texas and California furnish a fuel that, in addition to overcoming the limits of physical endurance of the fireman, also enables steam to be generated at a cost considerably below that for coal. This is illustrated by the Southern Pacific locomotive in Fig. 6.

Following these lines of increase, locomotives of more than two sections have been proposed in some cases in which the successive engines have received the steam in sequence, so as to form in effect a triple-expansion engine, and in other cases in which the steam has an expansive ratio of 2, obtained by exhausting from one pair of cylinders into two others. In order to keep down the length of the engine within reasonable limits, the tender can be made to do its share of the work, and, without increasing the length and only slightly the weight and expense, a locomotive can be constructed having about 50 per cent. more hauling capacity than a heavy Mallet type of locomotive as now in use.

The Mallet locomotive is no experiment, as many hundreds of them are in use in this country, but the triplex Mallets are still a problem for speculation and production. The first compound locomotive built by the Baldwin Locomotive Works was constructed in 1889, and, while the compound type of locomotive for a few years alter this was very strenuously sought on account of its fuel economy, it was found that there were other objections which, in many cases, overcame the benefits of reduced fuel consumption. With the introduction of the Mallet locomotive, however, the compound feature is of great importance, first.

Fig. 6.



Oil-burning Mallet locomotive.

as it reduces the amount of fuel needed to produce a given amount of power, thereby enabling a large locomotive to be successfully handled by an ordinary fireman, and, secondly, that the pressure of steam passing through the flexible joints is only about one-third of the boiler pressure, thereby reducing the difficulty of keeping these joints tight. When this type of engine was first placed in service it was feared that these ball joints would cause considerable difficulty, and, while some trouble has been found, this is being largely overcome as the round-house men become more familiar with the engines and expert in the packing of these joints.

There has been a type of locomotive introduced by the Borsig Company of Germany in which there are flexible wheels, these being mounted on tubular shafts through which the driving axle passes, so that, while the axles themselves are held in rigid boxes and operated from one pair of cylinders, the wheels can slide and swivel to adjust themselves to different degrees of curvature. We understand that these engines have given good service in certain localities in Europe, but we do not think that any of them have been introduced into this country.

ADJUNCTS AND DETAILS.

It is probably true that cast steel is more closely connected with the development of the large locomotive than any other single item entering into locomotive construction, and the possibility of being able to get large castings in this material has proved a very important factor in the advancement of this proposition. Some years ago steel castings were produced only in very small sizes by means of crucible furnaces, and such things as steel driving wheels, frames, foot-plates, etc., were unknown. With the large number of open-hearth steel plants making steel castings of high-grade material now in this country, there has been a great impetus given to the reduction of weight and increase of strength by substituting steel castings for iron castings and, in many cases, for iron forgings. In the former category probably driving wheel centres have been the most conspicuous examples, as even ten or fifteen years ago the axles and crankpins of locomotives were assuming such proportions that it made it difficult to obtain the proper strength with an iron casting. As the main driving wheel is subjected to a far greater stress than the other driving wheels, steel was first substituted in the main driving wheel only, but nowadays, when it is desirable to get the boiler as large as possible and thereby keep the other parts as light as possible, cast steel is used in many cases in all the wheels of a locomotive. It has now even become difficult to get along with cast steel, as, with the increased size of axles and pins and the inadvisability of increasing the stroke, we have gotten to such a point where there remains only 5 inches or 6 inches of metal between the axle and the pin fits, and when we consider that these are forced in with pressures from 100 to 200 tons it will be understood how difficult it is to produce a steel casting that will satisfactorily withstand forcing stresses and also those due to operation.

At first there was much difficulty in making driving wheels, as the rim would set in the mold long before the hub and fractured spokes would occur. This was overcome by separating the rim into sections so that the spokes could pull the rim towards the centre as cooling progressed. Later, however, the steel works found that they could cast these rims solid by uncovering the hub and arrange to cool that portion more rapidly so as to promote uniform contraction throughout the casting.

Foot-plates have been another very important example of the use of steel instead of iron castings. In olden times the foot-plate was often made unusually massive in order to add adhesive weight to the engine, but the great desire to produce boilers of maximum capacity has led to the use of foot-plates of cast steel, thereby reducing the weight very materially and allowing for greater boiler capacity. In such castings as these the weight of the piece in steel would be anywhere from one-half to one-third of what it would be in cast iron, and when this practice is followed through the different parts of the engine the great saving of weight is at once apparent.

Boiler supports, guide yokes, frame separators, and, in the Mallet type of locomotive, saddles connecting the frames and the cylinders, are now made of steel castings, and this metal is very much superior to iron in standing impact and even the effects of an unexpected collision.

In the replacement of forgings, cast steel has also rendered an important service; the most notable example of this is in locomotive frames. For years these were made of iron worked under the steam hammer, and, as the frames were of large sections, it was very difficult to properly weld the pedestals and braces together. When the sections were not over 4 inches in thickness there was little difficulty, but even then it was found that the welds, in spite of the best care, had often been imperfectly formed and would in service pull apart. With 5-inch frames, which are now common, and 6-inch frames, which are being introduced, this work would be very difficult, but cast steel permits the use of a section of almost any size. Then, too, the braces and all the parts are cast in one solid piece, so that there is less fitting and less opportunity for parts to become loose and work upon each other when the engine is in operation. Many of the more complicated forgings, such as equalizer beams, frame braces, and parts that have been made in the blacksmith shop, are now constructed of cast steel, often reducing the weight and at the same time the cost of manufacture.

In this country open-hearth steel is used almost exclusively for this material, but in Europe Bessemer steel with a comparatively high phosphorus content is much in vogue. This makes a smoother casting, as the phosphorus adds to the fluidity of the metal when being poured, but Americans are rather opposed to the use of Bessemer steel in important structures on account of its known liability to segregation and to crack under sudden strains. The open-hearth steel used for locomotive castings is both acid and basic, the former, of course, requiring a higher grade of pig to be used in its production. The great difficulty with steel castings at the present time is the tendency for piping and blow-holes to diminish the strength of a section at some part where it is impossible of detection before rupture, and, while this difficulty is being gradually reduced, largely by the careful study of proper design and the introduction of large sinking heads in molding, yet it must still be contended with and prevents us from using as high a fibre stress as we should if we could get rid of these objectionable features. Such steel has a tensile strength of from 60,000 to 80,000 pounds, which is fully double what can be obtained from cast iron, and, on account of its ductility and resistance to stand blows, it is superior to cast iron in even greater proportion than its increase in strength.

As yet little has been done in the use of cast steel cylinders in locomotives, although some few have been in service. As there is a tendency toward three-part cylinders—that is, a central saddle with a separate cylinder bolted at each side—the feasibility of using steel cylinders has been greatly enhanced. Of course, such cylinders have bushings of cast iron for both the piston and the valve, and, as the latter is nearly always of the piston type, the construction of a cylinder of cast steel is not especially difficult. The recent practice of using outside steam pipes materially assists in this problem.

Following the introduction of steel castings for frames, driving wheels, driving boxes, etc., alloy steel has also made its appearance in locomotive construction, and chrome vanadium or chrome titanium is frequently possible for the parts involving heavy stresses. The latter adds very little to the cost of steel per ton, and is thought by some to be practically as efficient as the high-priced vanadium steel. Nevertheless, there is difficulty being experienced, with both of these alloys, and when we consider that even the heaviest sections that we are able to produce now are hardly strong enough to stand such enormous piston loads, which in some cases reach to 140,000 or 150,000 pounds, the necessity for refinement in this line is apparent.

There has been little attempt to make such parts as connecting rods, parallel rods, etc., of steel castings, and the few attempts that have been made in this line have not been crowned with sufficient success to warrant extension in these particular details. Crank axles are seldom used in this country, but it has been found that the crank-webs in a built-up axle have given very good service when made of cast steel, but the forces in such a structure produce, principally, bending and torsion where steel castings are particularly satisfactory. In connecting rods, however, there is so much tension and compression that it does not seem wise to run the risk of using a metal that may have a blowhole or pipe at some critical part, and only high-grade hammered steel is used, as a rule, in these forgings.

While the Walschaerts valve motion has been recognized for many years as a suitable means for operating the valves on a locomotive, and has been used largely in Europe, it is only recently that its application to locomotives in this country has been worked out on a large scale. There have been many essays written upon the relative advantages of the Stephenson, which has been universally used, and the Walschaerts valve motion, so far as the movement of the valve itself is concerned, some claiming the Walschaerts gear with its constant lead was a great benefit, while others claim that the Stephenson motion with its increasing lead for early cut-offs is most desirable. Personally, we are inclined to agree with the latter theory. It is well known that a locomotive with a large amount of lead is very slow in starting, whereas one with a small or blind lead will be particularly active in getting under way and being reversed. With the constant lead of the Walschaerts motion it is necessary to settle upon some amount that will be satisfactory under ordinary running conditions, and this often produces a locomotive that is noticeably tardy in handling. In the Stephenson motion it is perfectly feasible, if desired, to set the valves line and line when the reverse lever is in the corner and have from ¼ inch to ⅜ inches lead when working at early cut-offs. This in itself constitutes a considerable advantage; however, it has been found by practical demonstration in road tests that there is no essential difference in either fuel economy or economy of train operation between the two methods of distribution, and for all practical purposes we can generally assume that the steam distribution and economy will be the same in both.

What, then, has given the impetus to the Walschaerts gear within the last decade, if there is no advantage to the valve movement, and, in fact, the possibility of a disadvantage? The answer is that it is simply caused by structural reasons. The Stephenson motion, with its inside links, while being well protected from damage by a side-swipe, has the disadvantage of requiring eccentrics, which, with the modern proportions of driving axles, have assumed very large dimensions, so large, in fact, that there is continual trouble in trying to keep them lubricated, as the weight and speed of the running surfaces have been increased with the enlargement of the axles. There is also considerable difficulty in suspending the link centrally, and, while it could be done, it was rather a troublesome and expensive arrangement. Perhaps the greatest incentive to remove the valve motion from under the barrel of the boiler was the fact that the heavy engines with long frames required cross-bracing, and when the eccentrics and rods are removed we have splendid opportunities for connecting together the frames with ample cross-braces. The increased weights have called for wider frames and long journals;

so that there is very little space left in which to place a satisfactory inside link motion.

The Walschaerts gear overcomes both of these difficulties, permitting not only a very comprehensive system of cross-bracing, if desired, but also eliminates the eccentrics and places the motion where it is very accessible. It has been claimed that the Walschaerts valve gear has fewer pieces and weighs less than the Stephenson, but when we consider the supports necessary to carry and suspend the various parts of the Walschaerts gear there is a great deal of weight and expense which, while it is not a part directly of the valve gear, yet is necessary to support the same. This results in an increased cost for the Walschaerts as compared with the Stephenson valve gear. In many cases these supports can be worked in as part of or an extension of the cross-bracing of the frames and boiler and produce a very simple and strong structure, and, taking everything into consideration, the change in valve gear has resulted in a very much better braced engine than was possible with the old Stephenson motion. There is no question, therefore, but that this valve motion is here to stay, in spite of the fact that many people consider the actual movement of the valve not as satisfactory as with the Stephenson arrangement.

With the large and heavy valves that must be moved in the modern locomotive the force necessary to operate the reverse lever has considerably increased. With articulated locomotives, which have two or more shifting valve motions, the work to be done is doubled or trebled; therefore, we are prepared to understand the second advent of power-reversing gears. It has probably been thirty years since the first steam reversing gear was used in this country, after a few years' use of which on a very small number of locomotives it was abandoned. In those days the valves were small and there was no difficulty in handling them very satisfactorily with the reversing lever. Now, however, the conditions are entirely different, and, in addition to the heavy weights to be moved, the wide fire-box prevents in many cases a good practical application of the time-honored reverse lever. In some cases it has been necessary to use a power reverse simply because a satisfactory hand reverse lever could not be worked in with the type of boiler used. These considerations are of sufficient importance to necessitate the complication of the power reverse gear, so that it is not likely that it will be relegated to oblivion, as was the attempt made many years ago.

There are several types of power-reversing gears, but we believe that the type in which the movements of the engineer resemble those of the ordinary reverse lever are most desirable, particularly when engines are placed in the chain gang and are not operated with a single crew. Thus, in the reversing gear which is illustrated by Fig. 7, the engineer simply pushes a small lever to the desired position and the reversing engine automatically moves the valve motion until it has assumed a position corresponding to the hand lever, and, while this hand lever may be reversed with a very rapid movement, yet the engine itself will pull the motion back slowly but surely, regardless of the speed with which the engineer has moved the controlling lever.

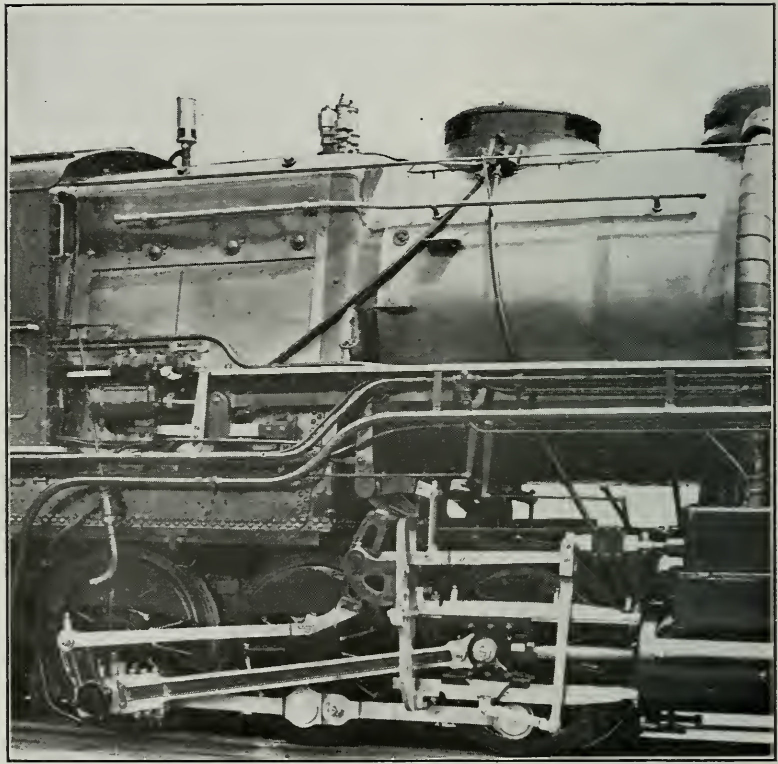
While piston valves have long been used in marine engineering, the general use of them in locomotives dates back a little more than ten years. The Vauclain compound locomotive with the high- and low-pressure cylinders superimposed, one above the other, was operated by a single piston valve for the two cylinders, this reducing the mechanism to a much simpler form than could be accomplished by means of slide valves. Previous to this there had been very few engines of the simple type equipped with piston valves, but the success which attended the use of the piston valve with the Vauclain compound induced its extension upon locomotives operated by single expansion only.

When the piston valve is used to replace an ordinary slide valve it is of a very simple type, and is practically a slide valve extended into a circle, with packing rings used at the several steam and exhaust edges. There has been considerable discussion as to the value of these valves as compared with slide valves, and a number of tests have been made, some showing better for one, some showing more economy for the other. There is little doubt but what this question of economy depends greatly upon the maintenance of the valve and the condition in which it is allowed to run, as a leaky valve of either type would, of course, be very wasteful of steam.

One of the principal advantages of the piston valve is the fact that it is fully balanced and easier to manipulate the engine than with a slide valve, even of the balanced type. As a matter of fact, piston valves are generally manipulated with greater ease when the throttle is open than when it is closed; still, the converse is true of balanced slide valves.

In spite of the fact that there is some doubt as to whether the piston valve is really more economical in steam consumption than the slide valve, yet they have been introduced in great numbers, parly due, no doubt, to the fact that the large cylinders require large ports, and the port opening with the piston valve can be made nearly double that possible with an ordinary slide valve. The large valves also are very little harder to handle in the cab than those of smaller diameter. Another advantage lies in the fact that piston valves can be, and generally are, so designed that the steam enters at the centre, or central admission, as it is called, and exhausts into the ends of the chamber, the valve being hollow, permitting both ends of the steam chest or valve chamber

Fig 7.



Power reverse gear.

to be in communication with each other. This reduces the pressure on the valve stem packing to that of exhaust steam only, and when it is considered that the variable travel of the valve makes it much more difficult to maintain packing on the valve rod than on the piston rod, which always travels the same distance and forms no intermediate shoulders, the advantage in relieving this packing of high pressure steam will be at once appreciated.

Reference was made above to the fact that in the Vauclain compound of the superimposed cylinder type one valve was able to regulate the admission of steam to both cylinders. In this case both the pistons worked together, being attached to the same crosshead. A later type of the balanced compound, in which the pistons move in opposite directions, has also been successfully worked by one valve, resulting in extremely simple mechanism for this type of engine.

The advantages of the Allen ported slide valve for the quicker admission of steam to the cylinders has long been appreciated, but this has not been generally introduced into piston valves, one reason, no doubt, being due to the fact that the much larger valve opening, on account of the greater length of port, made it unnecessary. With the increasing size of cylinders and the greater speeds at which it is desired to operate large tractive forces, it becomes necessary to adopt a somewhat similar arrangement for piston valves. This has been developed into the double ported piston valve, whereby there are two ports or openings, both for steam and for exhaust. The advantage of this is that a higher steam line or pressure line can be maintained in the cylinder up to the point of cut-off and less back pressure during the period of exhaust, as the steam has twice the area of opening when near the points of port opening and closure than could be obtained with an ordinary valve of the same size. As this port is placed partially in the valve chamber bushing, there is little additional complication added, except in making the valve itself, but the cylinder casting can be molded as easily in one case as in the other. While this is a very recent development, yet it promises such good results that we believe its quite general adoption is likely to be only a question of a short time.

While the boilers of locomotives have increased enormously in size, there has been little change in the actual design and construction. Of course, the larger diameters have given occasion for the introduction of thicker sheets and for joints of increased efficiency. The old double-riveted lap joint, which had an efficiency of about 70 per cent., has been superseded almost universally by the butt joint, with an efficiency of from 80 to 90 per cent. Besides reducing the thickness of the shell sheet, the butt joint pulls centrally and removes the cause of grooving, which was so often found when boilers were provided with lap joints, no matter how strongly they might be riveted. This grooving was due to the eccentric pull of the two sheets on the joints, and has been largely responsible for shell ruptures. It is, moreover, difficult to see before trouble ensues, but it reduces the section of the plate by starting a fracture at the caulking edge of the inside lap. The butt joint which has generally been introduced has a wide inside and a narrow outside cover plate, but in some cases the diamond joint has been introduced, which makes a very stiff shell at the joint. Seams have been welded, not only at the ends but sometimes for the whole width of the sheet, but, as a rule, a cover plate is put on in addition to the weld, so as not to depend entirely upon the welded joint. There are different ways of making these welds, sometimes by means of direct flame or fire, sometimes with an electric arc, and sometimes with acetylene, the latter coming now into more general use as the apparatus is portable and does not require connection with any source of power to provide current.

Cast metals have almost entirely disappeared from boiler construction, whereas in former times, with low pressures, it was considered permissible to use cast-iron dome rings and dome caps, yet these are now invariably made of pressed steel. The complete dome is sometimes pressed out of a single sheet of metal.

The fire-box itself has been affected principally by the introduction of flexible staybolts. These are generally of two types, one with a spherical end encased in a cup screwed into the sheet, of which the Tate is perhaps the best illustration, and another one consists of a hinged bolt, of which the "Breakless" is the best known example. These were introduced to reduce the great number of breakages which some lines experience, particularly in the corners or ends of the fire-box. Some roads even go so far as to specify that all of the fire-box staybolts shall be of the flexible type, while the majority of roads are satisfied to put in only 300 or 400 of such special bolts. These bolts add about 50 cents each to the cost of a locomotive, and the question has recently been raised as to whether they are really giving the immunity from breakage, which has been contended. The staybolt problem is rather a difficult question, inasmuch as if we make the bolt larger in diameter it will be stiffer and still less likely to stand transverse strain. With increasing pressures we cannot well make them thinner without reducing the spacing, and this is undesirable on account of the likelihood of the water space being choked up with mud. Then, staybolts are likely, if overheated, to let the crown sheet drop, and for this reason it is good practice to use button-headed bolts for the central rows of the crown sheet stays. The wide fire-boxes have long caused the practical disappearance of crown bars, so that there are practically either radial-stayed or Belpaire type of boilers in general construction at the present time. With the Belpaire the crown sheet is naturally level, but with the radial-stayed the high portion which would be first to be uncovered by low water is often protected by button-headed bolts. Some, however, think this a disadvantage and would prefer that a short section of the crown sheet should let go and relieve the pressure without pulling down the whole crown sheet. Records of locomotive boiler explosions, including dropped crown sheets, seem to indicate that less than 2 per cent. are due to deficient strength, and that practically all of the disasters are caused by low water, either through the negligence of the engineman or some difficulty with the water feeding or indicating devices.

In recent years the Jacobs-Schupert fire-box has been introduced as practically indestructible with even extraordinarily careless treatment in connection with fire and water. This boiler is composed of sections riveted to diaphragm sheets, so that no staybolt is used in the construction of the boiler, and some remarkable results of tests have indicated that it is very difficult, if not impossible, to cause a disaster by means of low water, even with a hot fire in the fire-box. Of course, this fire-box is more expensive to construct, and it is questionable whether the railroads would feel it necessary to pay this increased cost as an insurance against troubles of this kind.

The inside of the fire-box is occasionally provided with arches of various types; some of these rest on tubes and some on studs, some are made of solid bricks, and some are of hollow bricks with openings through the front water leg to introduce air for combustion. Some recent tests recently made showed that there was little, if any, efficiency or economy afforded by means of jets of air brought in through the arch brick, and the greater expense of the brick and the difficulty of maintaining them would seem to give preference to a solid brick, particularly if there was no gain over the hollow tiles. However, these questions of combustion have been so much discussed and disputed, and as results of different tests are likely to show such a variety of results, it is doubtful whether the question of the value of the brick arch and its various forms for admitting hot air, etc., will ever be satisfactorily settled in any one way to the community at large. Most people agree that the brick arch has a very positive value in connection with smoke abatement and fuel economy; yet in some sections of the country where the flues need frequent rolling and beading it is almost impossible to maintain an arch for any length of time, and it often prevents the quick turning of a locomotive, as the man cannot get in the fire-box or remove the arch until it has become sufficiently cooled. These practical considerations are often much more important in a locomotive than the mere theoretical consideration of fuel economy, as the business of moving trains is of primary importance, and anything that increases the round-house work or detains the locomotive at a terminal is bound to give way to the urgencies of transportation.

While the burning of oil instead of coal in locomotives is of quite ancient origin, having been first introduced in Russia on the Grazi-Tsaritsin Railway, it was experimentally tried in this country, but for many years had nothing to recommend it, as compared with coal, on economical grounds. The discovery of the fine deposits of oil in Texas and California, however, where coal costs $6 or $7 a ton in the latter locality, gave an impetus to this feature that was an immense benefit to the railroads in many ways. The Southern Pacific and the Santa Fe have for the last fifteen years been making considerable use of crude oil in the southwest, and in later years the substitution of oil for coal has been carried to points as far east as the Rocky Mountains and generally throughout the state of Texas. The advantages, while being enormous, have been also accompanied by certain disadvantages which prevented this from being an ideal fuel.

It was found from actual tests that four barrels of oil were practically equivalent to a ton of coal of the quality of Illinois bituminous, and, as there were usually six barrels of oil required to make up a ton weight, the ratio of heating value was as 3 is to 2. This is also in proportion to the number of British thermal units developed by burning a pound of these fuels, as mine run coal gives us in the neighborhood of 13,000 B.T.U. and fuel oil runs about 19,000 B.T.U.

Another incidental advantage that has been greatly appreciated in the last few years is that this oil can be put in without physical labor and makes it possible to keep steam up on a much larger engine than could be done with coal fired by hand. The unfailing source of steam is another advantage, as trains, even with the same tonnage, can make better time on heavy grades, as there is ample steam to keep the cylinders supplied at full pressure, no matter how hard the engine is being worked.

The universal method of generating steam from oil in a locomotive is by means of a special injector or atomizer, generally called a burner, in which the oil is sprayed by the steam pressure and is burned in this form of atomization. In order to maintain the combustion, the fire-box is lined part way up with fire brick, also having a floor of fire brick, which becomes quite hot and maintains the temperature high enough to ignite the oil. Formerly it was the custom to place the burner at the back end of the fire-box, spraying the oil ahead underneath a brick arch somewhat similar to the ordinary brick arches used with coal, but the latest practice is to place the burner at the front of the fire-box and spray the oil on a flash wall without using any arch whatever. This saves considerable expense, as the arch was very costly to maintain, sometimes falling down from the motion of the engine in two or three trips. It is also found by this location of the burner that the fire-box sheets give a longer life, as the intense heat of the oil flame causes a much more rapid deterioration than with coal, and especially was this found to be the case at the seams where two thicknesses of metal were exposed to the action of the fire. With the old method of using the arch, fire-boxes would often give only one-half or one-third the life of coal burners, and it was frequently necessary to renew a fire-box in about one year, very largely because it was impracticable to patch the fire-box on account of the double thickness of metal above mentioned. The new method of arranging the burner has increased this life, and the practice of welding in pieces flush with the acetylene torch has also obviated the double thickness of an ordinary patch.

Even in spite of the extra cost of maintenance due to rapid fire-box deterioration, the use of oil was considered very desirable, as a dollar's worth of oil would often replace three or four dollars' worth of coal. Then, there was practically no fire thrown from the stacks, which is of great benefit in a dry country, and this feature alone led to the adoption recently of fuel oil by the New York Central and the Delaware and Hudson Railroads on their lines running through the Adirondack Forest Preserve of New York State. This matter was discussed very thoroughly before the Second District Public Service Commission, which finally decided that these roads should burn liquid fuel during the summer season in order to prevent the extensive forest losses which had resulted from fire thrown from locomotive stacks or dropped from ash pans.

The firing of oil is, of course, a specialty, as the supply of fuel to the burner must be regulated in connection with the engineer's operation of the throttle and the reverse lever. When the engine is standing, the supply of oil must be cut down to a very small quantity, such that it will just be sufficient to maintain steam, and as soon as the throttle is opened a larger supply of oil must be given, depending upon the amount of steam required by the cylinders. It is perfectly feasible to fire a locomotive with fuel oil without the emission of smoke, except that in periods of about every half hour it is necessary to work sand through the flues in order to clean out the soot that has accumulated, and, of course, this is accompanied for a moment by the emission of dense black smoke. When the engine is working properly, however, there is only a thin haze above the stack, although the least inattention on the part of the fireman will cause either the steam pressure to drop or the emission of large quantities of smoke.

Practically any locomotive that is suitable for burning coal can be converted into an oil burner, although there are some particular features to be borne in mind when an engine is being designed primarily for the use of liquid fuel. It is a very simple matter to construct an oil tank which shall fit into the coal space of the tender, and this is connected with hose or flexible pipes to the engine, passing through a heater so that the oil may be rendered still more fluid, if necessary. Steam jets can be used to warm the oil in the tank when necessary, and there is generally a safety connection which, in case of the separation of the engine and tender, closes the oil valve, preventing it from running over the track. The California oils are ordinarily non-inflammable at the usual temperatures, and there is little or no danger attending their use. Some of the Texas oils, however, are more readily inflammable, and it is necessary to exercise extreme caution going about a tank with an open light. Asphyxiation is also liable to occur when men go inside of tanks to clean them out, particularly with the Texas oils, and these tanks should always be steamed out thoroughly before anyone enters to do any work. The actual cost of converting a coal-burning locomotive into an oil-burner varies from $500 to $800, dependent upon the size of the engine; but, of course, the incidental expenses, such as the maintenance of storage and delivery tanks, tank cars for transporting the oil and pumping it into the storage stations, are all part of the general cost of introducing such a system, and will oftentimes amount to a great deal more than the actual equipment of the locomotives.

The large locomotive, with its heavy draught of steam upon the boiler, necessitating the combustion of great quantities of coal, has brought about a number of appliances for diminishing the work of the fireman so that he can confine his efforts to actually delivering the coal into the fire-box; everything that could save a step or an extra motion of his hands or his back having in some cases been introduced, so that he could give the maximum output for the generation of steam. The old-fashioned fire door, which was swung with a chain and which was supposed to be opened and closed with each shovelful of coal, has been found troublesome in large engines, and, therefore, pneumatic fire doors have been introduced. These are arranged so that when the fireman has a shovelful of coal ready to throw into the door a pressure of the foot upon a treadle in the floor of the cab admits air to a small cylinder which slides each half of the fire door in opposite directions, thus opening the door for the admission of coal without any further action upon his part. As soon as the foot is removed from the treadle the door closes. This, besides relieving the fireman of the extra motion and effort, insures more perfect combustion, as the door is naturally closed after each shovelful of coal. Wide fire-boxes are in some cases provided with two fire doors, and it is not always as convenient for the fireman to use one door as the other, especially in connection with operating the fire door by hand, but these pneumatic devices prevent much of this trouble and assist very materially in the operation of firing.

The same principle has been applied to shaking the grates. While with short fire-boxes this was a comparatively easy operation, with the present length of furnace, which is in the neighborhood of eight and ten feet, and the width, which in some cases is eight or nine feet, it is not only necessary to shake the grates in sections, but it becomes quite difficult actually to do this work. Pneumatic or steam grate shakers have therefore been introduced in which a small lever operates the valve of a cylinder, which in turn gives the necessary travel to the grate arms in order to thoroughly shake up the coal bed to free it of clinkers and ashes.

Still another device has been introduced on the tenders in order to prevent the many steps needed when the coal has been partially exhausted and the fireman must go to the back of the tender coal space to shovel up the fuel. This mechanism consists principally of a steam cylinder placed inside the tank in which a piston is operated connecting to a false or inside bottom of the coal space, and when pressure is admitted to the cylinder the piston pushes up the back end of this false bottom, which is hinged to the front, allowing the coal to slide forward so it will be close to the gate and not require the extra steps and movement necessary in the ordinary type of tender.

While these different items seem small in themselves, yet, when they are all introduced together on the same engine, it is remarkable how much they save the fireman from a labor that can be performed mechanically as well as manually, and I have been impressed with this upon large locomotives where firemen have been enabled to put in very much greater amounts of coal than would ordinarily be expected.

The greatest improvement, however, has been in the development of the automatic stoker, which not only combines the several features above mentioned, but actually brings the coal from the tender and puts it in the fire-box. The first type developed was probably that invented by Mr. Kincaid, a former engineer on the

Chesapeake and Ohio Railway. This was really a steam shovel and placed back of the fire door, coal being thrown in the hopper from the tender by the fireman with a shovel, the apparatus, however, delivering the coal into the fire-box. This represented very largely the ordinary method of firing, as the fuel was thrown on top of the fire in the furnace and regulated the supply to be put in in large or small quantities and at regular intervals, so that the smoke production could be better controlled. There were means for distributing the coal to different portions of the box, and I have seen engines come in from a run with as level a fire as could be desired, the firing having been done entirely with this device.

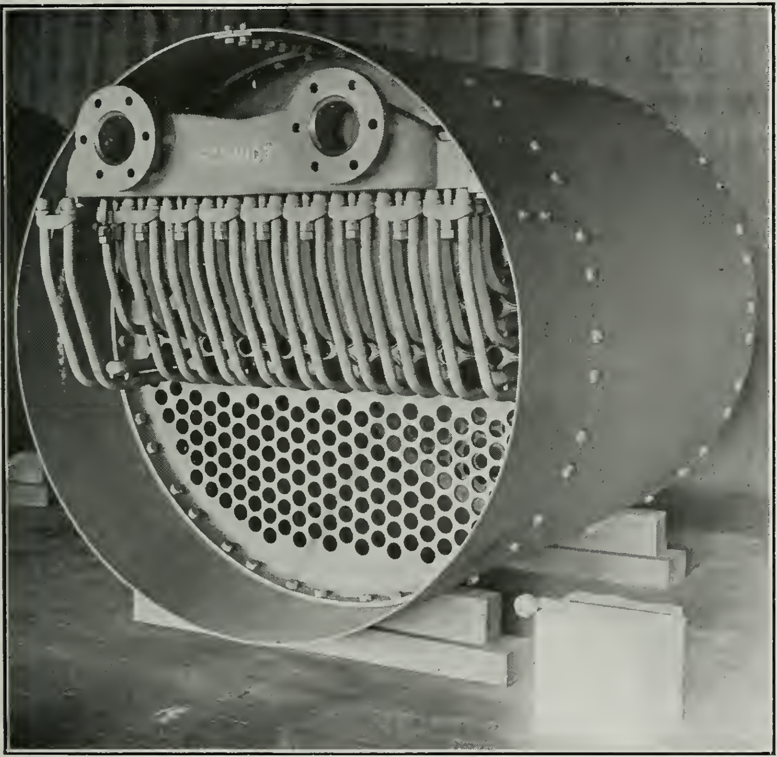
There was, however, no arrangement to take the coal from the tender to the stoker, and we think this is very important. Quite a number of stokers have recently been developed, in some of which coal is thrown in as in the Kincaid by a steam piston, the valve of which is moved by a small engine, the speed of which can be regulated, and in others the fuel is blown in by steam jets. There are also methods of introducing the coal below the grate, such as the Crawford and the Barnum stokers. In the first of these the coal is pushed forward under the grate by means of pistons through tubes and slowly pushes up and flows up over the grate. In the latter stoker this is done by the operation of worms similar to those used in flour mills. The coal in both cases is carried from the tender by means of worms or a conveyor. As the rate of combustion in a modern locomotive can be forced up to 200 pounds of coal per square foot of grate surface per hour, it is evident that the problem is not only to get sufficient coal into the fire-box, but also to get it in such condition that it will be ignited and burn at the desired rate. Naturally an underfeed device must be slower of ignition, but this takes care of itself, as the raw coal piles up over the slots and rolls over in the bright portions of the fire where the flame can reach to every surface of the piece and readily ignite it.

Claims for smoke reduction and fuel economy have been made, but really the principal point of the stoker is that it enables us to obtain more work out of the engine than would be possible with a human fireman. While the locomotive has increased in size and weight, its output in horsepower is generally very much below the increase in size, and, as previously stated, a very large engine will often develop no more actual horsepower than a much smaller one, although its tractive force will be very much greater. The limit seems to be the capabilities of the fireman, and, if this can be increased by mechanical means, not only will we be able to get more power from our engines, but the fireman's work, being less laborious, will be more attractive, so that higher-grade men can be obtained who will be able to use their heads and not depend entirely upon muscle and brawn for generation of steam.

Mention has been made above of the introduction of various superheaters and reheaters for use in connection with locomotive boilers in order to increase the output of the boiler and, incidentally, the fireman. The superheater has developed on three or four different lines—viz., one, in which a number of steam pipes are placed inside of the fire or smoke tubes, allowing the steam to be further heated by direct contact with the gases of combustion after it has passed from the boiler; another one, in which there has been a combustion chamber or pocket formed in the boiler itself, into which a receptacle has either been built or subsequently placed, permitting the steam to come in direct contact with the flue gases; and, third, in which a series of pipes are placed in the smoke-box of the engine to make use of the gases after having been discharged from the flues, the steam from the boiler passing through these pipes on its way to the cylinder. It is manifestly obvious that this latter method, using only the heat remaining in the gases after having been passed through the flues, will not receive as high a temperature as that which extends through the fire tubes toward the fire-box, but, at the same time, there are other advantages, several of which are that the heating surface of the boiler is not necessarily diminished by introducing this type of superheater, and that it can be applied to an existing locomotive, in many cases, without any material changes in the boiler. While the superheat obtained from the smoke-box type will average only from 30° to 50° Fahrenheit, yet the fact that the moisture in the steam is thoroughly dried out and that cylinder condensation is largely reduced, has made a very good economical showing for this type of superheater. Fig. 8 shows the Schmidt fire-tube and Fig. 9 the Vauclain smoke-box superheater.

With the fire-tube and chamber type of superheaters it is possible to get as much as 150° to 200° superheat, and some recent tests have been reported in which the temperature ran considerably higher than these figures. These superheaters, being exposed to the more or less direct action of the fire, are more liable to burn out than those in the smoke-box and are, also, as a rule, more expensive to apply and maintain.

FIG. 8.

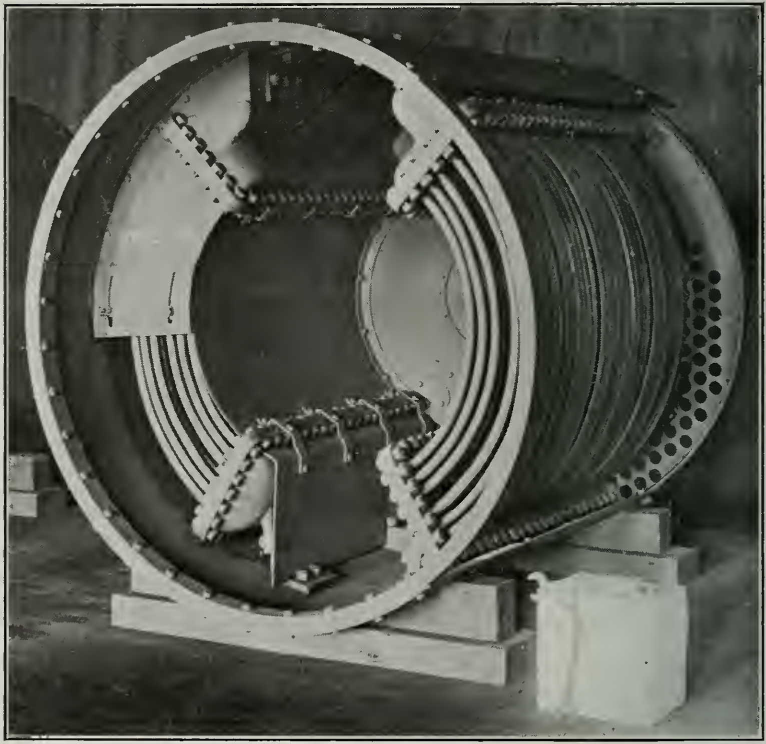


Schmidt superheater.

There are many varieties of fire-tube superheaters, and some of them are easy of access for removal of the superheating pipes and some are difficult. The tendency in recent designs, however, has been to develop a superheater in which the elements can readily be removed without necessitating the removal of many other parts, thereby delaying the engine in the round-house and keeping it out of service. This is an important factor in railroad operation, as no matter how much economy can be obtained from any device, if it were to cause much loss of time from actual service by requiring repeated and extensive repairs, it would not receive favorable consideration.

The action of superheat upon the work of a locomotive gives, as is well known, this advantage by increasing the volume of the steam delivered to the cylinders and, at the same time, the superheating prevents in a great measure cylinder condensation, as temperature of the steam must be lowered by the amount at least of its superheat by the processes of expansion before it can be condensed in the cylinders. The economy of superheat locomotives in coal consumption varies from 10 to 20 per cent., and

FIG. 9.



Vauclain superheater.

cases have been recorded where as high as 30 per cent. economy has been obtained. We think, however, that under ordinary service from 15 to 25 per cent. may be expected. This has an advantage in addition to the saving in fuel consumption, in that it also saves the labors of the fireman and enables him to give a greater output in horsepower for the same amount of physical energy expended.

It has been claimed that the increased volume due to the superheating could be utilized by operating at lower boiler pressures and thus reducing the amount of repairs on boilers of locomotives, which has become very onerous under conditions existing in modern locomotive practice; so that, even if there were no especial fuel advantage obtained, there would be a saving in boiler repairs. It must be borne in mind, however, that the loss in pressure in passing through superheaters is sometimes quite considerable, amounting to possibly 20, 30, or even 40 pounds per square inch drop from the boiler to the cylinders, and in order to make up for this and to maintain the proper working pressure in the cylinders it is necessary to operate the boiler at a considerably higher pressure than it is desired to supply to the cylinders. In Germany it is quite a common practice to have two gauges, one indicating the pressure in the cylinders and the other in the boiler, and the latter is carried so as to maintain the desired pressure in the cylinders. In this country 170 pounds is a rather favored pressure for superheater engines, and, of course, the cylinders are proportioned to give the proper tractive force with this pressure, thereby making the reciprocating parts larger than would be the case with high-pressure steam. Boilers are generally, however, designed capable of carrying 200 pounds per square inch, so that at any time the safety valves can be adjusted to allow for the drop in pressure passing through the superheater. Of course, it means a certain amount of lost work, and in some cases superheaters have been arranged in which the steam passes through a single loop in the fire tube instead of the double loop, as ordinarily used. This would naturally reduce the loss about 75 per cent., and this means a great advantage in the operation of the engine.

The action of the fire on these inside tubes when steam is not passing is sometimes prevented from overheating them by means of an automatic damper in the smoke-box, which closes when no steam is passing through the superheater, thereby preventing the overheating of these pipes.

With superheaters of the chamber type it has been found that the large volume of steam outside of the throttle at times prevents a prompt response of the locomotive to the engineer's movement of the throttle lever; in starting, for instance, this chamber must fill up with steam before the pressure will accumulate in the cylinders sufficiently to move the train, and upon closing the throttle the expansion of this steam causes the engine to run farther than would otherwise be the case. It has been suggested that the throttle valve be placed outside of the superheater in order to overcome this difficulty, but this, of course, has been open to the objection that when standing the superheater might fill up with water, endangering the cylinders when the engine is started.

The whole superheater question is, in a measure, in its infancy, and, while there are a great number in use, yet we do not feel that there has been a sufficient amount of experience with them in this country so that all the benefits and difficulties can be as yet definitely determined. Anything that will increase the output of a locomotive will be looked upon with favor, unless, as stated above, there may be delays owing to necessary repairs that may more than make up for the efficiency of the engine when in operation. Of course, it must always be remembered that such devices have their benefit only when the engine is actually working steam, as on an up grade, or working on a level. During times of running down hill, standing at stations or terminals, remaining on side tracks or in the round-house, these advantages are absolutely unavailable.

From a number of tests made at the Purdue University by Professor Goss, in which the running of the engine was intermittent, they found that the steam consumption per unit of work delivered was increased, due, no doubt, to the cooling of the cylinders and the connected parts, and that this loss increased with higher steam pressures. When the programme of operations was intermittent with equal periods of running, the loss was found to be from 5 to 10 per cent. more than that under constant running, and when the reduction by stack losses and periods of idleness were also considered, the results were about 20 per cent. less favorable than during constant operation. This, however, does not consider the absolute uselessness of this or any other device when the engine is running down hill or standing, and the additional expense for its original application to a locomotive means a constant interest charge. These things should all be considered in making any final estimates as to the value of this or any other economical device, but they are too often overlooked in the enthusiasm of those who are anxious to make a saving in coal consumption.

Reheaters have much the same function as superheaters, except that this term is applied to such devices as impart heat to the steam in its passage from the high-pressure to the low-pressure cylinders. The low-pressure cylinder, naturally, is that which produces the greatest amount of condensation, and, if we are able to reheat the steam after it has exhausted from the high-pressure cylinder, we will save considerable condensation in the low-pressure cylinder. Reheaters are seldom used alone, but are generally used in connection with superheaters which heat the steam before passing into the high-pressure cylinder. The exact amount of saving to be accomplished by a reheater is not definitely known, but it is probably somewhere in the neighborhood of 5 to 10 per cent.

Reheaters are generally either of the box type or of the smoke-box type, and in design they resemble an ordinary superheater of these two varieties.

Feed-water heaters are of a similar nature and construction, although they are generally made of the box type. The flexible boiler makes a very convenient use of the front section by placing therein a reheater, and even in some cases with rigid boilers where the length would be too great for the application of tubes satisfactorily a feed-water heater is placed in the front end and the water from the injectors flows through this feed-water heater, which is warmed by the gases of combustion after passing through the flues.

It has been customary, in many cases, to run with this section full of water, the water then passing from the top to the boiler, being fed in near the bottom of the feed-water heater. The electrolytic action, however, in many cases causes trouble and pitting of the flues and sheets, although the boiler itself is not affected in a similar way. This seems to be worse in good water districts than where scaly water is used, and it is thought to be due to the oxygen carried in with the water. The latest practice has been to connect this with the steam space directly and run it at the same level as the water in the boiler, making this really an extension of the boiler, and, while it seems somewhat strange that such should be the case, the economy, which is from 5 to 10 per cent., seems to be practically the same whether this acts entirely as a heater or whether it is connected up to form an extension of the boiler.

ELECTRIC PROPULSION.

In the last ten years the wonderful advancement made by electricity in all lines of work has led some to believe that the days of the steam locomotive are actually numbered and that it would soon become a thing of the past. This belief has been expressed by some men of high standing in political affairs, if not in mechanical, and the great successes attending the application of electricity to street-car lines, suburban transportation, elevated and subway roads have rather brought about a popular opinion harmonizing with the above-mentioned assertion.

The difference between the operation of a street-car system, suburban system, elevated or subway railroad is so entirely different from the operation of the average steam railway that there is really little actual comparison between the two. Estimates have been made upon the cost of operation of a steam line, based upon the results found when the elevated railway lines in New York City were electrified, by comparing the new results with those of the old steam operation, and it was only a few years ago that some electrical engineers of considerable reputation advanced the theory that if all the steam railways in the country were to be electrified a saving in the cost of operation would be made which, while not quite equal to that claimed by Mr. Brandeis, would be effected by adopting economies, yet would be well worth considering as means for economical operation.

No one can deny for a moment the great advantage to city and suburban life of the trolley car, and it is this, probably more than anything else, that has given our cities an outlet for their increasing population and made suburban life a happiness instead of a drudgery; but even this has not been altogether without financial disappointment to the electric railway companies, as only a few years back many of them were being sold under foreclosure and only really made money when operating upon a new basis of cost, which had the result of very materially scaling down their fixed charges.

When we consider the application of electricity to the New York Central Terminal tracks in the city of New York, it is often asserted that this substantiates the theory of the devotees of electric propulsion, and this has been made such capital of by electrical engineers in order to enforce their pet schemes, which have been, no doubt, largely developed by over-enthusiasm in their particular line of work. As a matter of fact, the profit of operating the New York Central Terminal line by electricity over the steam lines is not large, and the capital expenditures have been something enormous. It was stated several years ago by the vice-president in charge of electrification that the consequential costs were about four times the actual costs of electrification, by which he meant the arrangement of depots, tracks, terminals, roundhouses, and other facilities which would necessarily enter into the electrification. The fact that there is a margin of profit was shown very clearly in a paper presented to the American Society of Civil Engineers by the official mentioned above, an analysis of which showed that if the actual amount of traffic or the load factor had been less regular there would have been an increased expense instead of an economy. To make this somewhat clearer, we would state that if the power requirements had been so irregular that the facilities of the power-house would need to be doubled to carry the movement over the maximum peaks there would actually have been an extra expense, but, on account of the uniformity of movement, the power-house equipment could be so adjusted that the interest on investment was not so great as to overcome the economy effected in the actual movement of the trains.

On the other hand, it has been but a few months since the New York, New Haven and Hartford Railroad claimed an increased cost of operation, due to electrification, when this subject was considered for the application of similar conditions to the Boston territory, and, at the best, it would seldom, if ever, be claimed that the economy resulting from electric operation will ordinarily be so great as to make it an attractive financial proposition for the substitution of electricity for steam. There are other conditions, of course, besides the financial part of the problem, such as existed in the tunnel under Park Avenue in New

York City, where steam operation was almost intolerable to patrons of the road, not only from the liability to accidents, but from the partial suffocation which everyone experienced in going through the tunnel in hot weather. The question of relieving the city of the smoke of the locomotives was also an important consideration, and it was these features and *not* the prospect of financial improvement that forced the electrification upon these roads, and we believe that we may well say "forced," as they certainly would never have gone into this project had they not been driven into it by the residents of New York City and the commuters who daily passed through the inferno of the Park Avenue Tunnel.

The consequential damages referred to above can sometimes be reduced or made into an actual asset by utilizing the space which would not be available under conditions of steam operation. This is illustrated by the New York Central construction which is now being completed in New York City. The large amount of open space required for the escaping of the gases and steam from the locomotive smokestack can, in the case of electric operation, be reduced to a very small quantity, and the overhead space so vacated by steam and smoke can be utilized for office buildings and other purposes. Of course, this depends largely upon the locality, and there are comparatively few places in the world where this would be as remunerative as in New York City. It is a phase of electrification, however, that should be given due weight when considering the financial returns on any scheme of this kind.

On the other hand, we must consider what actually happens in the way of transportation density and uniformity on many of the railroads in this country, and perhaps we should say on nearly all of them, outside of a few in the most populous districts. It has been claimed that the one requirement for successful financial electric operation was density of traffic, but we believe that uniformity is just as important as density. For instance, let us compare a road like the New York, New Haven and Hartford Railroad or the Pennsylvania's Atlantic City line. Here the passenger travel is great at all times of the year, and is quite uniform during the day and night, so that frequent train service is required at nearly all hours. In this case we have not only density but uniformity, and, as stated above, it is this item that gives us the saving in the electrical operation to the New York Central's Terminal System. The same is true of the New York

Elevated, which runs trains very frequently at all hours of the day and night, maintaining a high load factor, which, while there are peaks, to be sure, yet these peaks are not so far above the average movement as to require an excessive expenditure for installation in the power-house.

From this let us go to the other extreme and consider a line in the West where there is very little local traffic, except that on one or two nights in a week a heavy stock business exists to bring cattle to the following day's market. This business is onerous and exacts and requires high speed and delivery at the expected time without fail; otherwise consequential damages may be assessed against the carrying road. It is not uncommon for this division, which may see two or three trains a day ordinarily, to have twelve or fifteen heavy stock trains pass through it in the course of a few hours at some one or more times during the week. These trains are usually sent in fleets in order to insure better dispatching and also to enable them to arrive in suitable time for the next day's market. The amount of power required on this division at this particular time would be extremely high. If we consider such trains (and they are run at high speeds requiring about 2,000 horsepower for their operation) and that fifteen are handled, we see at once that each division power-house must be sufficient to give at least 30,000 horsepower output. The rest of the week the output would probably not be over 3,000 or 4,000 horsepower at any one time, so that a large amount of machinery must be installed in the power-house to carry this exceptional peak load, and this machinery is non-remunerative for the other six days a week and represents idle investment. This must be repeated at every division power-house which is used to provide power for such a movement, and shows at once the futility of arguing that electrification would be applicable to all roads. The steam locomotives can be bunched, grouped, and transferred from one division to another and make a particularly elastic medium of power transmission, as the next day the locomotives can simply be placed upon another division where their services will be needed; moreover, the cost of a horsepower represented by steam locomotives is approximately $15 each, whereas a modern power-house with the transmission lines will cost fully $100 per horsepower, to say nothing of the fact that electric locomotives are nearly double the price of steam locomotives.

These conditions are brought to your attention, not with the idea of belittling by any means the use of electricity for transportation purposes, or of trying to prevent extensions in that line, but are simply presented so that these matters may be so clearly understood that the enthusiasm of some electrical experts may not be permitted to get the best of sound judgment, which will eventually react and injure the cause more than it will help. On the other hand, we would not be surprised at any time to learn that the Pennsylvania Railroad, for instance, would electrify its entire system between New York and Washington. The present New York Terminal is operated entirely by electric locomotives; the subject is being now studied in regard to Philadelphia; the tunnels at Baltimore will certainly soon require heroic treatment; and, in order to prevent the objectionable smoke in the capital of our country, electric traction would be considered a great advantage. These four links in a line 250 miles long, and the density and uniformity of traffic which passes over these divisions, make this quite an attractive subject for electrification, but there can be no comparison between this piece of track and that above described, and which is found in most of our western States.

We have refrained from going into figures on this subject, as statistics are difficult to properly interpret, unless they are given in great detail and carefully analyzed, and the different factors entering into the subject are so varied that it requires a great deal of study to actually determine the line between gain and loss. Each individual case must be studied under its own conditions, and only in a general way can we draw deductions from one existing line with which to prognosticate safely the results of some other line. There is no question but that electric traction will increase, but we believe that steam traction will increase still more rapidly, and that the steam locomotive will not be relegated to the museum or the scrap pile during the life of any one present at this meeting.

There are three different ways in which electric locomotives can be operated: first, by collecting the current as the locomotive moves from either a trolley wire or a third rail; second, by means of storage batteries carried on the engine or tender; third, by means of internal combustion or other motors generating electricity as required which actuate motors geared to the axles. The first method has certain advantages not enjoyed by the others, and is the one generally employed for handling heavy trains through long distances. The great advantage which results from this arrangement is that the full output of the power-house is available at the motors and the capability of doing work is limited only by the characteristics of the motors installed upon the engine. It is possible with such a combination to obtain much greater tractive forces with high speeds than can ever be hoped for with a steam locomotive, because the latter is dependent upon the capacity of its boiler and fireman, whereas the electric locomotive can receive its power from a plant which will deliver many more horsepower than could possibly be obtained from a locomotive boiler. It is this phase of the question which has been urged so largely in the endeavor to place electric locomotives on heavy grades and mountainous sections, but, outside of some special pieces of track where tunnels make the operation of steam locomotives objectionable, there has been little done in this country along this line, and, although such plans have been investigated, they have not ordinarily been found to be financially attractive. There is no question but what there are great possibilities in this line, provided that the costs are not out of proportion to the benefits developed. The motors, of course, have certain limits, principally governed by their ease of disseminating heat, and it is the heat limit that prevents more power being put through any given motor. There have been cases in the West where even water power, with its generally attractive features, has not been considered as a satisfactory financial proposition; where the cost not only of producing but of transmitting the electric current from the water power to the railroad was found to be too great a financial burden to expect an equivalent return.

For comparatively short lines with dense and uniform traffic, however, there is probably no other method which is likely to be considered, the choice lying between the third rail and the overhead trolley suspension. Both systems have their advantages and disadvantages, but either can be operated satisfactorily, as demonstrated by the locomotives used on the New Haven Road, which, while on the direct current territory of the New York Central, collect from a third rail, and when on the alternating current sections of the New Haven collect from an overhead wire. The motors in this case are single-phase and can be used either on direct or alternating installations. In the latter case the current is transmitted and used at a high voltage, namely, 11,000, while in the direct current the ordinary voltage is 660. It is this difference in voltage that makes it feasible to use third rails with low voltage, which would be considered unwise with the voltages used on the New Haven overhead line. Even at certain points the low voltage direct current must have overhead connections, as at complicated switches and crossings where a continuous third rail is not practicable, but that both systems can be operated satisfactorily is amply demonstrated not only by the trolley car service with its suburban connections, but by the several steam lines which have divisions operated electrically.

There are certain places, however, where it seems impracticable to use satisfactorily either the overhead trolley or the third rail, and these are in freight and classification yards where much shifting is necessary and a great number of switches are encountered. The necessity for men moving on foot over such a yard to do their work in connection with the makeup of trains renders the third rail a very serious obstacle, and the presence on top of box cars of brakemen giving signals, etc., renders an overhead wire dangerous and unattractive. For such a condition, either a steam locomotive burning anthracite fuel or with some smoke-consuming device that is effective can be used, or a locomotive operated with a storage battery, which is, perhaps, the most attractive proposition. These batteries can be carried in a separate car or tender and can be recharged and simply picked up by the locomotive, discarding its discharged battery car when necessary. Of course, the expense of such a locomotive is high, and it is possible that some special batteries like the new Edison quick-discharge and recharge battery would alone be acceptable, but the expense, of course, would not be as great as the installation of third rails and overhead wires, and the locomotive has the advantage that it can move on ordinary track, pass into and out of private yards and buildings without any restrictions, and can simply replenish its current when necessary as a steam locomotive would take on coal and water. On account of the great cost of these locomotives, however, which is principally involved in the storage battery, it is not likely that such a system would be developed to any great length of line, but for terminal work and switching around a number of spurs and individual properties it seems like a very attractive proposition.

The internal combustion motor generating its own current has been made use of in a number of isolated cases, and for branch service and where the service is light and the trains few it answers the purpose admirably. This, however, is also quite an expensive machine, as we must have the power generated converted into electricity and back again by the motors into power, which makes an elaborate system of machinery, and, while it answers the purpose well for branch service, it would not be satisfactory for hauling heavy trains in main line work. The cost of operation of such motors is comparatively low, but the principal saving is in reducing the number of men in the crew. A single car can be operated with two men, whereas the least number that could be run with a steam locomotive and passenger cars would be four men. The uncertain cost of gasolene is also a factor in this method of operation, which is not entirely satisfactory, and when it comes to taking care of such a machine it is certain the car shed will not be a suitable place for doing this work, nor will the roundhouse be appropriate for the passenger portion of the vehicle. We therefore believe it safe to say that for heavy main line work either the third-rail or the trolley system will be found most acceptable, and that the second and third systems above described will be found useful adjuncts for certain parts of a railroad system, but that they cannot be seriously considered for heavy through traffic.

The type of electric locomotive which collects current as it moves, whether by trolley or by third rail, has individual characteristics considerably different from the steam locomotive. Several general arrangements are in use which might be divided ordinarily into three different types: first, that in which the motors are mounted directly on the driving axles of the locomotive, although this does not mean rigid connection, as they are generally arranged to turn the driving wheels through a flexible connection; second, that in which the motors drive the axles through the medium of spur gearing; and, third, that in which the wheels are driven through connecting rods. In the early days of the development of electric locomotives the first arrangement was considered the most desirable, as the centre of gravity was brought quite low and there was an absence of connecting and transmitting machinery. For many years the increasing heighth of centre of gravity of locomotives has been a bugbear to railroad men, and, when the very low centre of gravity produced by the first arrangement of locomotive was proposed, it was considered that this would be practically ideal. One or two disastrous wrecks, however, led to a more careful study of this question, and one railroad made an elaborate series of tests with different types of steam and electric locomotives, both on straight line and curved, to determine what arrangement of wheels, etc., gave the least strains upon the track.

While the high centre of gravity is more dangerous by overturning the locomotive at excessive rates of speed, yet there is no question but what the low centre of gravity puts more stress upon the outer rail of the curve and its tie connections. This may be illustrated by the accompanying diagram, in which it will be seen that while the centrifugal force is the same for locomotives either with high or low centre of gravity with the weight, speed, and radius of curvature the same, yet the high centre of gravity throws an increased weight upon the outer rail, thus forcing it more tightly to the ties and reducing the shearing effect of the horizontal centrifugal force. The later electric locomotives which have been built for the Pennsylvania Railroad are operated by a single motor connected to the wheels by means of an inclined connecting rod. This gives the advantage of concentrating the power into one motor, which is generally more efficient, and also raising the centre of gravity more to the conditions of a steam locomotive. The geared locomotive raises the centre of gravity to a position between the connecting rod and the engine in the gearless type, but does not concentrate the effort into a single motor.

A technical discussion of the details and characteristics of these different types would be out of place in such an article, and all of them are giving very satisfactory results in service, but the principal points of interest have been referred to so that in a general way some idea could be had of the line of thought leading to these three varieties.

As to the question between direct and alternating current, each has its advocates and each has some advantages not possessed by the other. Alternating current motors, when of the single-phase type, can be so constructed that they will operate on either direct or alternating current, although a motor that is built for operation on only one, will be more efficient and lighter than a locomotive built to operate on both circuits. One of the principal reasons for increase in weight in the combination locomotive is due to the fact that it must be provided with both resistance grids for the D. C. current and auto-transformers for the alternating current. With the direct current, the speed regulation is arranged by using the series or parallel operation in connection with reducing the voltage by passing it through resistance coils or grids. This is wasteful and is only intended to be used in starting and under certain conditions of slow speed. The alternating current varies the voltage by means of taps taken off from different parts of the transformer coil, and is free from the wasteful resistance of the direct current means of regulation. Both types can be coupled up to provide multiple unit control, so that one, two, or more sections can be used in accordance with the needs of the train to be hauled. The leading unit only need be occupied by the motorman and assistant. With such a combination there is almost no limit to the amount of power which can be developed, as each unit is limited only by the heat characteristics of its motors. Regardless of the great power which can be supplied by such units, however, the service so far performed in this country is nearly all passenger, and little freight work is being done by electric locomotives on trunk lines. Of course, this statement is not strictly true if we consider such cases as the Baltimore tunnels of the Baltimore and Ohio, the tunnel under the river at Detroit, and the Sierra Nevada tunnel of the Great Northern, and other points where steam operation would be particularly objectionable; but, outside of a few special cases such as above mentioned, the electric service is confined almost exclusively to passenger transportation.

Formation of Petroleum. C. ENGLER. (*Petroleum*, vii, 399.) —This is an extension of the author's theory that petroleum is produced from organic remains. The residual fatty substances (including waxes, resins, etc.) left after the decomposition or putrefaction of the protein, cellulose, etc., are considered to be gradually converted into anabitumen (soluble in benzene, carbon bisulphide, and other organic solvents), which undergoes further changes into other forms of bitumen; *e. g.*, polybitumen, katabitumen, ecgonobitumen or crude petroleum, oxybitumen or asphaltum. The results of his recent work in conjunction with Routala and Halmai are then adduced to explain the production of the different types of natural petroleum from a common source.

Crystolon (silicon carbide).—Amorphous silicon carbide, in the form of "carborundum fire sand," makes a good lining for electric-resistance furnaces, and is also useful in fuel-fired furnaces as bricks, or lining, or even as a "wash" applied to the firebrick walls. It is also used for repairs and as a firebrick cement. It becomes somewhat plastic at a very high temperature, and can be used without a binder. At still higher temperatures, in a reducing atmosphere, it is converted into crystalline silicon carbide. The heat conductivity of amorphous silicon carbide is higher than that of firebrick. Crystalline silicon carbide, or crystolon, is still more refractory than the amorphous form; it has a higher heat conductivity even than alundum and a smaller coefficient of expansion than silica. For making shaped articles of crystolon, powdered silicon carbide may be molded with the aid of a temporary binder, such as glue or dextrine, and then heated in an electric furnace to the temperature of formation of silicon carbide, whereupon crystallization or re-crystallization of the carbide takes place and a strong article is obtained. Bricks made in this manner serve well as a roof for electric furnaces. Owing to their high heat conductivity these bricks must be backed with a course of firebrick or other heat-insulating material; and the electrodes should just fit the openings in the firebrick, but have a clearance in passing through the crystolon, as this is a conductor at high temperatures. Crystolon articles made with a small amount of clay binder, however, act as insulators for most practical purposes even at high temperatures. In some experiments in an electric furnace with a crystolon brick roof it was possible to destroy the magnesite lining of the furnace and to melt the firebrick covering the crystolon, without damaging the latter.

Electrically calcined magnesia.—Magnesia calcined at a very high temperature in an electrical-resistance furnace is practically free from the defect of cracking, when heated to high temperatures, that is shown by ordinary calcined magnesia. The electrically calcined magnesia absorbs carbon dioxide so slowly that it is practically negligible.

Fused lime.—Lime fused in an electric furnace is a much better heat conductor than ordinary quicklime, and withstands sudden cooling after heating. It is much less readily hydrated.

New Electric Bicycle Lamp. ANON. (*Amer. Mach.*, xxxvi, 16, 615.)—A new electric bicycle lamp has been introduced in Amsterdam, the electricity for which is generated by the operation of the bicycle. A small wheel attached to the shaft of the dynamo rests on the front or rear wheel of the bicycle, making several revolutions for each one made by the larger wheel. When the lamp is not needed, this small wheel is released by a lever from the bicycle wheel. At a speed of 15 kilometres (9.32 miles) per hour a very powerful light is obtained, but a lower speed gives sufficient light.

A GENERAL FORMULA FOR THE TORSIONAL DEFLECTION OF SHAFTS.*

BY

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Introductory.—In a previous article,[1] by considering the internal work of deformation, the writer has derived a general formula for the shearing deflection of beams of arbitrary cross-section, either variable or constant. By the same method, a new and simplified proof of the Fraenkel formula for flexural deflection was also obtained in this article, and it was further shown that all the ordinary formulas for either flexural or shearing deflection are special cases of one or other of the above. Practical application of these formulas was then made to the calculation of the deflection of a planer rail for which both the cross-sectional area and moment of inertia were variable.

The object of the present article is to complete this work on deflection by deriving a general formula for torsional deflection. The usual analysis of torsional deflection, as given by St. Venant, Bach, and others, involves a more extensive knowledge of higher mathematics than possessed by the average engineer. The derivation here given, however, is very brief, and involves no mathematical principle more difficult than elementary integration.

Internal Work of Torsion.—In deriving the general formula for torsional deflection, the following notation will be used.

Let W = internal work of deformation under torsional strain,
G = modulus of shear (or modulus of rigidity),
ρ = unit angular, or shearing, deformation,
T = external torque or twisting moment applied to the ends of the shaft,
q = unit shearing stress due to torque T,
q' = unit shearing stress due to unit torque,
A = area of cross section of shaft.

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* Communicated by the Author.

[1] JOURNAL FRANKLIN INSTITUTE, April, 1911.

Then if dV denotes the volume of an element of the shaft, the internal work of deformation on this element is

$$dW = \frac{1}{2} q\phi \, dV,$$

or, since $dV = dA.dz$, where dz denotes an element of length of the shaft, and also since, by Hooke's law, $\frac{q}{\phi} = G$, this may be written

$$dW = \frac{q^2 dA \, dz}{2G}.$$

Consequently the total internal work of deformation is

$$W = \frac{1}{2G} \int_0^l \int_0^A q^2 dA \, dz.$$

For a prismatic shaft—that is, one of constant cross section—this expression may be integrated with respect to z, and thereby simplifies into

$$W = \frac{l}{2G} \int_0^A q^2 dA.$$

It should be noted that this is a surface integral, and hence when rectangular coördinates are used it becomes a double integral, as shown in the applications which follow.

Theorem.—Let ϑ_1 denote the angle of twist, or torsional deflection, produced in a prismatic shaft by a unit torque, say one foot pound. Then the angle of twist ϑ actually produced by any given torque T will be $\vartheta = T \vartheta_1$. Now let W denote the work of deformation produced by a torque $T + K$. Then if K is increased by an amount dK, the angular deflection is increased by an amount $\vartheta_1 \, dK$, and consequently the total work W is increased by an amount dW such that

$$dW = (T + K)\vartheta_1 dK.$$

In this expression the work done by dK itself is neglected, since it is infinitesimal in comparison with the work done by $T + K$. Hence

$$\frac{dW}{dK}=(T+K)\vartheta_1,$$

and therefore, since $\vartheta = T\vartheta_1$, the angular deflection ϑ produced by the torque T is given by the expression

$$\vartheta=\left[\frac{dW}{dK}\right]_{K=0}.$$

This result is analogous to Castigliano's theorem on the deflection of beams.

Derivation of Formula.—Let q_0 denote the total unit stress due to the combined torque $T+K$. Then

$$q_0=q+Kq^1$$

where a and b denote the semi-axes of the ellipse. Consequently the expression for the work of deformation due to $T+K$ becomes

$$W=\frac{l}{2G}\int_0^A(q+Kq^1)^2dA.$$

By the theorem just proved, therefore, the angular deflection ϑ produced by the torque T is

$$\vartheta=\left[\frac{dW}{dK}\right]_{K=o}=\left[\frac{l}{2G}\int_0^A 2(q+Kq^1)q^1dA\right]_{K=o}=\frac{l}{G}\int_0^A qq^1dA.$$

Since $\frac{q}{q^1}=\frac{T}{1}$, or $q^1=\frac{q}{T}$, this becomes

$$\vartheta=\frac{l}{GT}\int_0^A q^2dA,$$

which is the required general formula for the torsional deflection of a prismatic shaft.

Applications.—Circular Shaft.—Consider a cross-section perpendicular to the axis of the shaft and choose a pair of rectangular axes OX, OY in the plane of the cross-section and intersecting at the centre O of the circle. Then the component shearing stresses at any point of the circular cross-section with coördinates x, y are

$$q_x = \frac{2Ty}{\pi R^4}, \quad q_y = -\frac{2Tx}{\pi R^4}$$

where R denotes the radius of the shaft. Hence the resultant shear q at this point is

$$q = \sqrt{q^2_x + q^2_y} = \frac{2T}{\pi R^4}\sqrt{x^2+y^2}$$

and consequently

$$\int_0^A q^2 dA = \frac{16T^2}{\pi^2 R^8}\int_{y=0}^{y=R}\int_{x=0}^{x=\sqrt{R^2-y^2}}(x^2+y^2)dxdy = \frac{2T^2}{\pi R^4}.$$

Therefore the total angle of twist for a round shaft is

$$\vartheta = \frac{l}{GT}\int_0^A q^2\, dA = \frac{2lT}{G\pi R^4};$$

or since the polar moment of inertia of a circle is $I = \frac{\pi R^4}{2}$, this may be written

$$\vartheta = \frac{Tl}{GI}.$$

The angle of twist per unit of length, say ϑ_0, is, in this case,

$$\vartheta_0 = \frac{\vartheta}{l} = \frac{T}{GI}.$$

Elliptical Shaft.—For an elliptical cross-section the component stresses at any point x, y, referred to the principal axes of the ellipse as coördinate axes, are

$$q_x = \frac{2Ty}{\pi ab^3}, \quad q_y = -\frac{2Tx}{\pi a^3 b}$$

where a and b denote the semi-axes of the ellipse. Consequently the resultant shear at the point x, y is

$$q = \sqrt{q^2_x + q^2_y} = \frac{2T}{\pi a^3 b^3}\sqrt{a^4y^2 + b^4x^2}.$$

The surface integral becomes in this case

$$\int_0^A q^2dA=\frac{16T^2}{\pi^2a^6b^6}\int_{y=0}^{y=b}\int_{x=0}^{x=\frac{a}{b}\sqrt{b^2-y^2}}(a^4y^2+b^4x^2)\;dxdy=\frac{T^2(a^2+b^2)}{\pi a^3b^3}.$$

Therefore the total angle of twist ϑ is

$$\vartheta=\frac{l}{GT}\int_0^A q^2dA=\frac{lT(a^2+b^2)}{G\pi a^3b^3},$$

and the angle of twist per unit of length ϑ_0 is

$$\vartheta_0=\frac{\vartheta}{l}=\frac{T(a^2+b^2)}{G\pi a^3b^3}.$$

Since the polar moment of inertia of an ellipse is $I=\frac{\pi ab(a^2+b^2)}{4}$, the expression for ϑ_0 may also be written

$$\vartheta_0=\frac{4TI}{G\pi^2a^4b^4}=\frac{4\pi^2TI}{GA^4}.$$

Triangular Shaft.—For a triangular cross-section, the stress at any point depends on the relative dimensions of the triangle. In the present case consider an equilateral triangle, choose the origin of coördinates at the centre of the inscribed circle and one axis parallel to a side of the triangle, as shown in the figure (Fig. 1). Then if the radius of the inscribed circle is denoted by a, the component stresses at any point x, y are

$$qx=\frac{5T}{9\sqrt{3}\,a^4}\left(y-\frac{xy}{a}\right),\qquad qy=\frac{5T}{9\sqrt{3}\,a^4}\left(-x+\frac{y^2-x^2}{2a}\right).$$

Consequently the resultant stress q at this point, is

$$q=\sqrt{q^2x+q^2y}=\frac{5\sqrt{3}\,T}{54a^5}\sqrt{4a^2x^2+4a^2y^2+2x^2y^2-12axy^2+4ax^3+x^4+y^4}$$

and the surface integral becomes in this case

$$\int_0^A q^2dA=\frac{25T^2}{486a^{10}}\int_{x=-2a}^{x=a}\int_{y=0}^{y=\frac{x+2a}{\sqrt{3}}}(4a^2x^2+4a^2y^2+2x^2y^2-$$

$$12axy^2+4ax^3+x^4+y^4)dxdy=\frac{5T^2}{9\sqrt{3}\,a^4}.$$

Hence the total angle of twist is given by

$$\vartheta = \frac{l}{GT}\int_0^A q^2 dA = \frac{5lT}{9\sqrt{3}\,Ga^4};$$

and the angle of twist per unit of length becomes

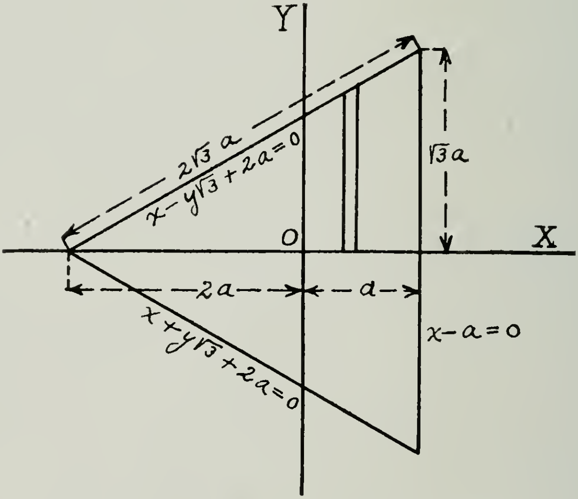
$$\vartheta_0 = \frac{\vartheta}{l} = \frac{5T}{9\sqrt{3}\,Ga^4}.$$

Since the polar moment of inertia of the triangle with respect to the origin, or centre of gravity of the triangle, is $I = 3\sqrt{3}\,a^4$, this may also be written

$$\vartheta_0 = \frac{5T}{3GI}.$$

Rectangular Shaft.—For a rectangular cross-section with sides of length a and b, choose the origin at the centre of gravity of the rectangle, and the axes parallel to its sides. Then the component stresses at any point x, y are

FIG. 1.



$$q_x = \frac{9T}{a^3b^3}\,y(a^2 - 4x^2), \quad q_y = -\frac{9T}{a^3b^3}\,x(b^2 - 4y^2).$$

Consequently the resultant stress q at this point is

$$q = \sqrt{q^2_x + q^2_y} = \frac{9T}{a^3b^3}\sqrt{y^2a^4 - 8a^2x^2y^2 + 16x^4y^2 + b^4x^2 - 8b^2x^2y^2 + 16x^2y^4}$$

and the surface integral becomes

$$\int_0^A q^2 dA = \frac{324T^2}{a^6b^6}\int_{y=0}^{y=\frac{b}{2}}\int_{x=0}^{x=\frac{a}{2}}(y^2a^4 - 8a^2x^2y^2 + 16x^4y^2 + b^4x^2 - 8b^2x^2y^2 + 16x^2y^4)dxdy = \frac{36T^2(a^2+b^2)}{10a^3b^3}.$$

The total angle of twist for a rectangular shaft is therefore

$$\vartheta = \frac{l}{GT}\int_0^A q^2 dA = \frac{3.6lT(a^2+b^2)}{Ga^3b^3},$$

and the angle of twist per unit of length is

$$\vartheta_0 = \frac{\vartheta}{l} = \frac{3.6T(a^2+b^2)}{Ga^3b^3}.$$

Since the polar moment of inertia of a rectangle is

$$I = \frac{ab(a^2+b^2)}{12},$$

this expression may also be written

$$\vartheta_0 = \frac{43.2TI}{Ga^4b^4} = \frac{43.2TI}{GA^4}.$$

Square Shaft.—If the cross-section is square, then $a = b$, and the expression just obtained reduces to

$$\vartheta_0 = \frac{7.2T}{Ga^4}.$$

Radium Content of Secondary Rocks. ARNOLD L. FLETCHER. (*Phil. Mag.*, vi, 23, 279.)—In 82 specimens of secondary rocks the radium was determined by the fusion method. With the exception of the small and relatively unimportant class of calcareous rocks, all the secondary rocks were found to contain very nearly the same quantity of radium, viz., 1.4×10^{-12} grammes per gramme. The mean found for the calcerous sediments was 0.8. The coarse detrital sediments contained somewhat higher amounts of radium, on the average, than the fine, classed as argillaceous and schistose.

Siloxide, a Valuable Substitute for Quartz Glass. F. THOMAS. (*Chem. Zeit.*, xxxvi, 25.)—Siloxide is the name given to products prepared by fusing silica with small proportions of refractory acidic oxides, such as zirconia or titania, for the purpose of obtaining materials more resistant to the action of metallic oxides, especially alkalies, than quartz glass, and being less liable to devitrification on heating. Specimens of Z. siloxide or zirconium glass and T. siloxide or titanium glass were examined, and, although these did not exhibit the beautiful silky lustre of quartz glass ("vitreosil"), they possess distinct advantages over the latter with respect to strength, thermal properties (resistance to devitrification), and resistance to the action of alkalies. The zirconium glass with the most strength contained 1 per cent. of zirconia, while that which had the best thermal properties contained 0.5 per cent. The titanium glasses (containing 0.1 to 2 per cent. of titanium) have a somewhat lower resistance to compression than quartz glass, but resist transverse fracture better than the latter and are superior even to zirconium glass as regards their thermal properties.

Colloidal Gold and Platinum. N. PAPPADA. (*Zeit. Chem. Ind. Kolloide*, ix, 270.)—Colloidal gold and platinum solutions, especially the latter, are much more stable than other electro-negative sols. such as Prussian blue, copper ferrocyanide, etc. The sols prepared by Bredig's method of cathodic disintegration are much more stable than those prepared by chemical reduction methods. The activity of electrolytes in causing coagulation of gold and platinum hydrosols follows in general the same order as with other electro-negative sols. Colloidal gold and platinum act as reducing agents, but are much less active than colloidal silver. When colloidal gold is treated with potassium cyanide or hydrocyanic acid, the dark violet color changes to yellow, and the colloidal character is destroyed, for even tri-valent cations such as Al''' or Te''' now fail to produce flocculation. Colloidal gold acts energetically with chlorine, forming gold chloride. With iodine the reaction proceeds much more slowly. Colloidal platinum acts similarly.

Upkeep of Shop-Lighting Systems. C. E. CLEWELL. (*Amer. Mach.*, xxxvi, 13, 501.)—This paper on shop lighting is of considerable interest, and indicates the economy of keeping lights clean and efficient. In brief, attention is drawn to some of the items involved in the maintenance of shop-lighting systems at high continuous efficiency. From the stand-point of economy alone, the expense is justified. When to economy are added the comfort and assistance that a well-regulated system gives to employees, the matter becomes yet more important. The outlay for lighting upkeep is more than compensated by the better illumination, more contented employees, and a more cheerful shop.

SYMPHANY IN STEREOSCOPIC RADIOGRAPHY.[1]

BY

P. H. EIJKMAN, The Hague, Holland.

Three years ago I published some new methods of stereoscopy and pointed out that from a mathematical point of view Roentgen-ray stereoscopy is a much simpler problem than ordinary stereoscopy with a photographic camera with lenses. With Roentgen rays the object and its projection are on the same side of the centre of projection, whereas with the camera they lie one on either side of this point, and the image is therefore reversed. With the camera, owing to the position of the conjugate foci, the ratio of the distances is fixed, but with the Roentgen rays this is not the case. With the rays, the plate may be at any angle, although I only considered the "normal" case, so as to simplify the construction. I pointed out the mistake of applying the laws of lens stereoscopy to Roentgen stereoscopy, since, in my opinion, the simplest way is to derive ordinary stereoscopy from Roentgen stereoscopy. The so-called "pin-hole camera" is a transition stage between these two; in this the law of conjugate foci does not apply, and there is no principal axis.

I showed that, for the mathematical reconstruction, the two Roentgen plates, or their virtual images, must be superimposed exactly at the same spot and in the same position with regard to the two anticathodes. Further, since the anticathodes must be replaced by the eyes, the distance between the two anticathodes (base of exposure) must be equal to the distance of the optical centres of the two eyes (visual base). In practice this distance may be taken as 65 millimetres.

I stated, thirdly, that the following conditions are requisite for the normal stereoscopic exposure:

1. In the two exposures one plate must be placed exactly in the same place as the other; in other words, the plates must be congruent.

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[1] Presented at a meeting of the Section of Photography and Microscopy held Friday, March 8, 1912.

2. The base of exposure—*i.e.,* the distance between the two positions of the anticathode—must be 65 millimetres.

3. The nearest point of the object must be at least 25 centimetres from the anticathode, since at a lesser distance the eyes do not see stereoscopically.

4. The base must be parallel to the photographic plate, and the middle point of the base opposite the middle of the plate. We may call the perpendiculars from the extremities of the base the "principal axes," and their intersections with the plate the "foot-points."

All other cases may be considered as deviations from the normal exposure, and may be easily deduced from that.

I have worked constantly, since the time of making these statements, to develop these methods, the first of which I named Polyphany.

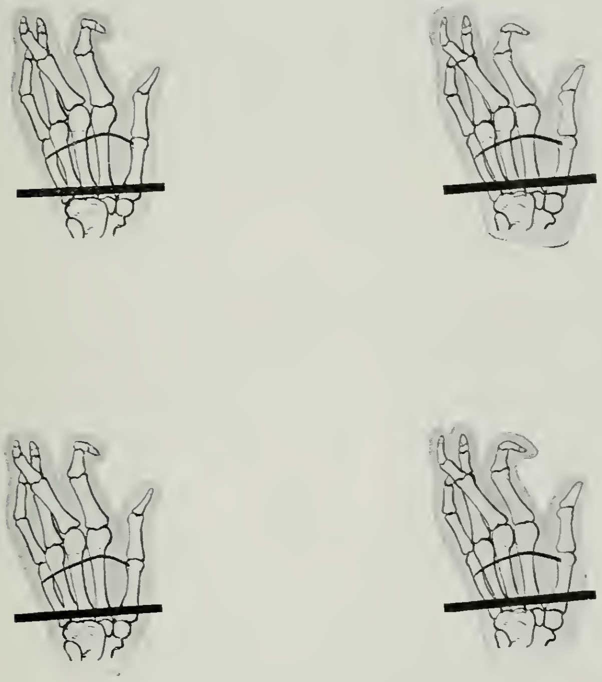
The pictures made both by ordinary light and by X-rays are what we term, in mathematics, central projection, and, in stereoscopics the connection between the two stereoscopic half-images is expressed by the fact that the exposing distance is the same for both, while the centres of the two projections are separated from each other by a definite distance, which we call the "base-length." It will be readily understood that we may make any number of half-images from points which satisfy these requirements. A given half-image is not limited to one definite complementary half-image, but may be combined with any one of these. The question thus arises whether it may not be of advantage in practice to make the stereoscopic exposure from more than two points. A simple experiment will answer this question in the affirmative.

If we hold a cylindrical stick in a horizontal position at a short distance from the eyes, both eyes will receive one and the same image of the stick, and what is hidden from one eye by the stick is also hidden from the other eye.

It is quite different, however, if we hold the stick in a vertical position, for then the left eye sees objects behind the stick hidden from the right eye, and the right eye sees what is hidden from the left. A similar phenomenon may be observed with the Roentgen rays if we place a thick wire parallel to the base before taking a stereoscopic skiagram. There is no representation on either plate of what is situated before or behind the wire, so that it is impossible to decide whether this wire is placed before or behind the object itself. If, however, we place the wire perpendicular to the former direction, we can see quite clearly at what depth the wire is situated.

Fig. I shows a skeleton hand, in which the fingers are placed in an unnatural position. Four exposures were made, the respective projection centres making a square of 65 millimetres in a plane parallel to the plate. A metal shaft was placed under the hand in a transverse direction. If we hold the plate so that the fingers point upwards, and examine the two lower images through the stereoscope, we cannot distinguish whether the metal staff is behind or in front of the hand.

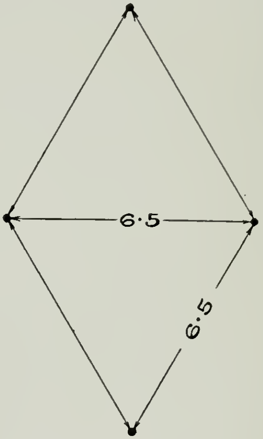
FIG. I.



Tetraphany: Plate with a set of four images.

Likewise, if we look at the two uppermost pictures, we are still in doubt as to the position of the metal staff. Mathematically speaking, one has now obtained all the information derivable from these four pictures. Psychically speaking, however, this is not the case. When we turn the plate on its side and examine what is now the upper pair of pictures in the stereoscope, we obtain at once an accurate impression of the position of the metal staff, and on viewing the other pair we get a like result. Other details, such as the shape of the fingers, are also shown much more clearly. This, in my opinion, proves that a series of four such skiagrams, that may be viewed two by two in various ways, has a decided advantage over the usual pair of stereographic negatives. I have named this Tetraphany.

FIG. 2.



Tetraphany in lozenge shape: Position of the centres of projection.

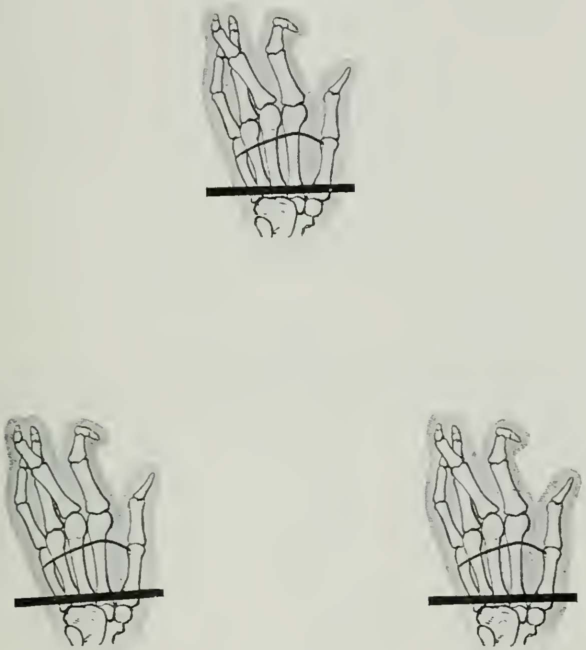
If, instead of a square, we take a lozenge with one diagonal equal to the base, as in Fig. 2, we may obtain five combinations from the four negatives.

The result is almost as good as if we made three such negatives, with the centres of projection at the angles of an equilateral triangle (Triphany), as in Fig. 3. In practice a threefold exposure will probably be sufficient. With the usual oblong shape of photographic plate, it is advisable to place the foot-points of the principal axes in the position shown in Fig. 4.

Instead of placing the three anticathodes at the angles of an equilateral triangle it may in certain cases be advantageous to place them in a straight line.

The X-ray worker knows very well that it makes a difference in what direction he takes stereoscopic pictures of the ribs, and that they are best taken in such a manner that the stereoscopic base is not parallel with the ribs. A triphanic picture of a skull shows that some parts of it are better seen with the base line of the eyes parallel to one base, while other parts are clearer with the base line of the eyes parallel to the base line of another pair of views.

FIG. 3.



Triphany: Plate with a set of three images.

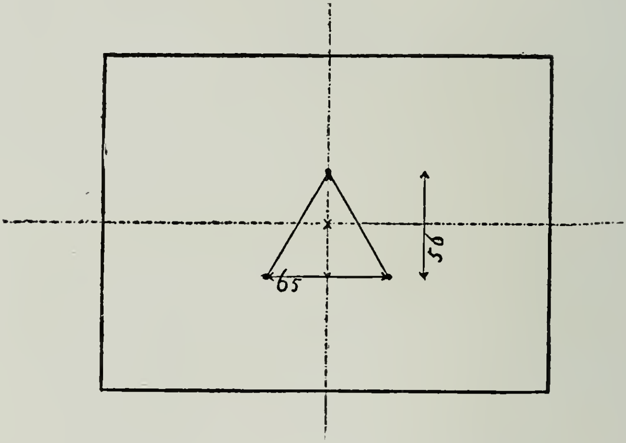
For the examination of pictures in Triphany it is simplest to have a lens stereoscope with three lenses, the centres of which make an equilateral triangle having sides of 65 millimetres.

The principle of Polyphany, which I have thus described for Roentgenography, may also be made use of for any other variety of stereoscopy.

The term Symphany relates to the simultaneous and coincident examination of an object by ordinary physical light and X-rays.

In making a stereoscopic picture with X-rays, the body to be radiographed is placed over the plate, with the X-ray tube at some convenient distance. One picture is then taken, say with the tube positioned on the left. A second radiograph is made after changing the plate without disturbing the body, but with the X-ray tube moved to the right. Since, for the mathematical reconstruction, the anticathodes must be replaced by the eyes, the distance between them (base of exposure) must be equal to the distance of the optical centres of the two eyes (visual base) of the operator.

FIG. 4.



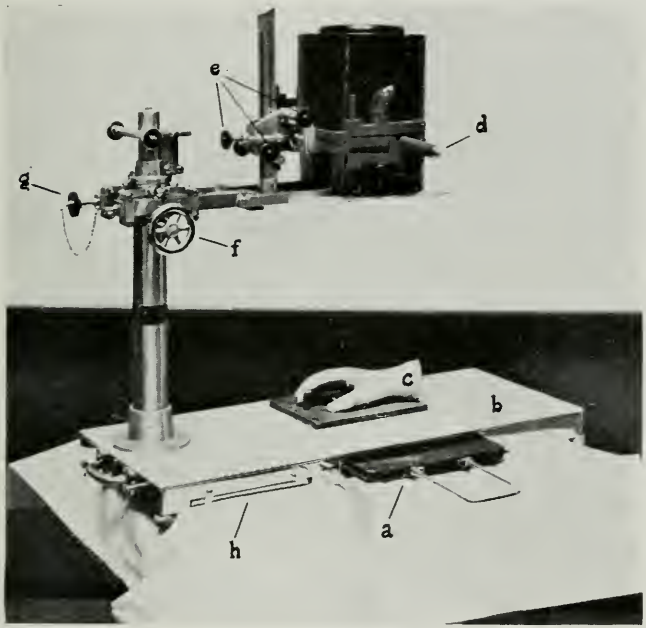
Triphany: Position of the three foot-points on the plates.

In the mathematical reconstruction by a mirror stereoscope the virtual images must coincide with the original position of the plates. The stereo-image appears on the exact spot where the object lay, exactly the same size and exactly the same shape, so that we may say the stereo-image is congruent with the original object.

It is very readily seen that the operator, having an exact reconstruction, can, by using transparent mirrors instead of ordinary opaque ones, superimpose the solid virtual X-ray image upon the original body, causing the external contour of both solid images to coincide exactly. In the human body one will thus see the bones through the skin in their exact relative positions. This may serve as a guide to the surgeon during an operation, since he is able to apply his scalpel to the desired spot with mathematical accuracy. This method—*i.e.*, the contemporaneous presence of the object itself together with its Roentgen-ray image—may be termed Symphany.

By removing the object one sees only the Roentgen image as a nebule of a distinct form. With a piece of white paper every point of this solid image can be touched, indicating in three dimensions exactly where the point lies. A divided rule may be held across this virtual stereo-image in any direction and the exact distance between those two points ascertained. This method, which I call Symphanometry, should prove of use for scientific measurement. In the stereogram is thus possessed not

PLATE I.

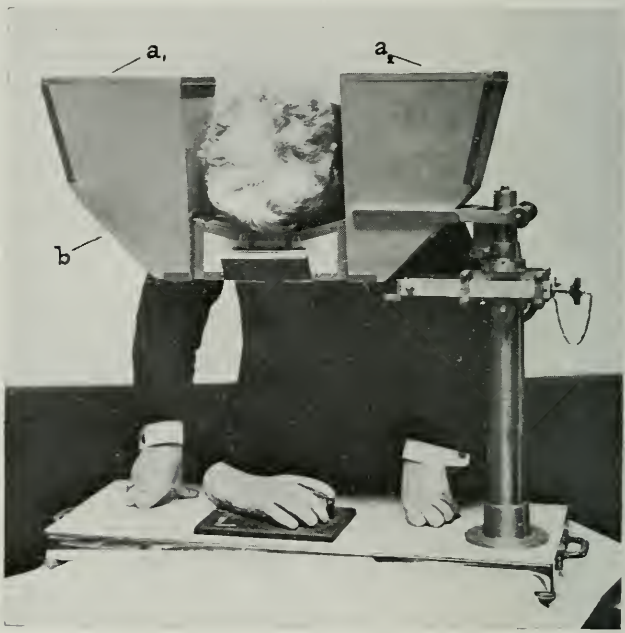


Apparatus arranged for making the two stereoscopic radiographs: *a*. Double plate-holder (plates changed by turning the holder over). *b*. Aluminum sheet. *c*. Body. *d*. Roentgen-ray tube. *e*. Screws for the tube adjustment. *f*. Wheel for the stereoscopic displacement of the Roentgen-ray tube. *g*. Screw for the adjustment of the displacement. *h*. Note-book.

only a means of giving a general psychical impression, but also a register of the actual mathematical proportions. Perhaps this method could be of value in obstetrics for giving an exact notion of the shape of the pelvis.

In certain cases it might be of advantage to make a permanent record by combining X-rays with the ordinary photographic stereogram. To perform this effectually the centre of projection must coincide exactly with the optical centre of the lens system of the camera, and the displacement must be the same in both cases.

PLATE 2.



The symphanor in position: a_1, a_2. Radiographs. *b*. Mirror set at 45°. The observer looks at a pair of small transparent mirrors.

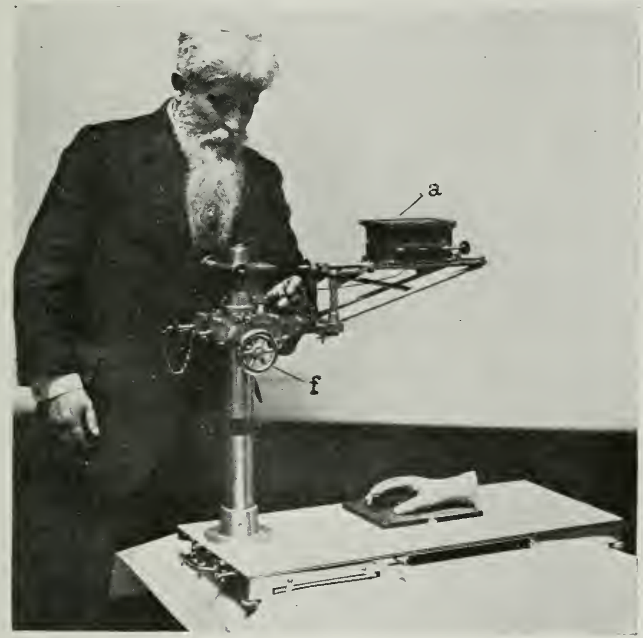
With the same camera one can reduce the X-ray pictures of an object to the same size as the photographic pictures of that object. Then, by using stereoscopic lenses with transparent mirrors at 45 degrees, so that the two sets of pictures can be viewed at the same time, they will be seen to be quite congruent.

On account of the apparent difficulty of a physician troubling himself with so much mathematics, I endeavored to make an instrument that would do this work quite automatically.

In the *Proceedings of the Royal Academy of Sciences of Amsterdam,* March 17, 1909, I gave the full theory. This was reprinted in the *Archives of the Roentgen Ray,* June, 1909.

It was only in the first week in March of this year that I received my first working model from the manufactory of Reiniger Gebbert and Schall (Erlangen), and I have to thank Messrs. Kny and Scheerer for giving me an opportunity for testing the apparatus.

PLATE 3.



The photographic camera in position: *a.* Photographic camera. *b.* Wheel for stereoscopic adjustment.

I highly appreciated the opportunity of demonstrating it recently, for the first time, before the Academy of Medicine of New York, and now experience the same pleasure in showing it to you.

Boiling-point of Sulphur. (*Engineering,* xciii, No. 2401, 24.)—The exact boiling-point of sulphur has often been determined on account of its importance for thermometry. Messrs. C. W. Waidner and G. K. Burgess (see Bureau of Standards Bulletin, vol. vii, No. 11) have made a new contribution to this research. They boiled sulphur in a Callendar Griffiths apparatus, comprising a glass tube 4.5 cm. in diameter, 45 cm. high, the thermometer coil being mounted within a porcelain tube and enclosed in a radiation shield, 15 cm. long; the resistance thermometer had a length of about 5 cm. The temperature of the sulphur vapor appeared constant within 0.03° C. over a length of 30 cm. of the vapor column. Determinations were then made with thermo-couples of platinum and platinum-rhodium, or platinum-iridium, immersed to different depths, and these were less concordant. Considering that a long resistance thermometer is an integrating device giving average temperatures, the constancy of the boiling-point of sulphur, which is complex in its chemical behavior, possesses several valencies, and is known in several allotropic modifications, appeared doubtful. Other experiments were therefore conducted with a very short resistance thermometer, only 9 mm. long, and with various thermo-couples, finally made of very fine wires only 0.1 mm. in diameter. By this means satisfactory agreement was obtained, and the boiling-point of sulphur appears to be 444.7° C. and to be experimentally constant within at least 0.05° C.

"Pergamyn" Papers. (*French Patent* 435, 589, Oct. 23, 1911.)—Fancy "pergamyn" papers, with greater translucency in some parts than in other parts, are manufactured by preparing a pulp refined in the usual way for "pergamyn" papers and disturbing the moist felt of fibres on the wire of the machine, so as to obtain flaky deformations or more compact agglomerations of the fibres, and finally submitting the paper to heavy pressure at an appropriate stage of the drying process. The desired deformation is produced by a press roll placed at a suitable position above the wire, which is supported at the place by an arrangement fixed underneath. Owing to the irregular distribution of the fibres, only the projecting lumps become compressed under the heavy pressure subsequently applied, so that the paper becomes translucent at these points.

An Alloy for Safety-Valve Seats. (*Brass World,* viii, 4, 120.)—A cobalt-chromium alloy for use as safety-valve seats has been patented by Elwood Haynes, of Kokomo, Ind. It is called "stellite," and can be made of any required degree of hardness, hard enough for use in cutlery, if so desired. It is very non-corrosive, even more so than nickel, and rivals gold and platinum. Its value as a safety-valve seat lies in that it does not wear and never corrodes.

NOTE ON THE RIDEAL-WALKER PHENOL CONTROL.[1]

A Possible Discordant Factor in the Standardization of Disinfectants.

BY

J. T. AINSLIE WALKER, F.R.S.M., F.C.S., and JOHN MORRIS WEISS, B.S., B.A.

WITH the development of chemistry as a quantitative science, used in many and diversified industries, a pressing demand for pure reagents arose. Methods for insuring the purity of chemicals used in quantitative analysis were developed, and to-day this feature has been brought to a state of high perfection. Bacteriology, on the other hand, is in the incipient stage of development along quantitative lines, and most phases are still empirical. One feature which to-day is susceptible of exact quantitative determination is the bactericidal standardization of disinfectants. This is best exemplified by the Rideal-Walker test,[1] which, briefly, consists in comparing the strengths of disinfectants which kill B. typhosus in a definite time under carefully standardized conditions with the strength of pure phenol solution necessary to perform the same work under the same conditions. Various modifications have been suggested from time to time.[2] [3] [4] [5] [6] [7]. All, however, use pure phenol as a standard, and on the purity of this standard depends the accuracy of the test.

All previous workers have used the Koppeschar bromine titration method [8] as the means of measuring the purity of their phenol control. This is admirable, so far as the detection and elimination of water are concerned, but it totally fails to indicate another and far more serious impurity.

Phenol, or pure crystal carbolic acid, is almost entirely manufactured from a distillate oil of coal-tar by an extraction process, with subsequent purification by distillation and crystallization. In these processes it is possible to produce a very pure phenol, but ordinarily this is not done. Phenol from such a source always contains some of the next higher homologues—the cresols—the amount varying with the care given to the manufacturing process. The bromine titration does not indicate the presence of moderate amounts of cresol in phenol, returning both in terms of the latter, the analytical variations due to this cause being negligible. As cresol has approximately three times the bactericidal efficiency of phenol, the error from this cause, as will be shown later, may be a very considerable one. The purpose of this communication is to present a new method for insuring the purity of phenol used in determinations of the bactericidal efficiency of disinfectants, and to show by experiment that the cause mentioned above probably accounts for many of the discordant results obtained in the past by different investigators. To insure a pure phenol as a basis for work, the material was synthesized from pure benzene by the Wurtz, Kekule and Dusart sulphonate method, and the product fractionally distilled twice to eliminate water and small amounts of by-products formed in the reaction. The crystallized phenol thus obtained had a solidifying point of 40.5° C. Although some authorities place the melting point of pure phenol at figures varying from 40 to 42.5° C., yet it has been conclusively shown by Eger[9] [10] that the highest purity of phenol has a solidifying point of not over 40.9° C. In view of the fact that our solidifying point was taken on a thermometer recently checked by the United States Bureau of Standards, and that the phenol itself boiled within very narrow limits (0.5° C.), we felt justified in considering that our phenol was absolute, and that the figures as to melting point reported by earlier investigators were incorrect, either because of inaccurate thermometers, or from having to deal with too small quantities of material.

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[1] Presented at the meeting of the Section of Physics and Chemistry held Thursday, April 25, 1912.

Mixtures of this pure phenol were then made with pure cresols, and it was found that with percentages of cresol from 0 to 30 the lowering of the melting point was constant for any particular degree of impurity, regardless of the variation of the proportions of the three isomeric cresols making up this impurity. The solidifying points were taken on at least 50 c.c. material with the thermometer in the liquid. The point is very sharp, as the thermometer shows a constant temperature over a period of from five to ten minutes.

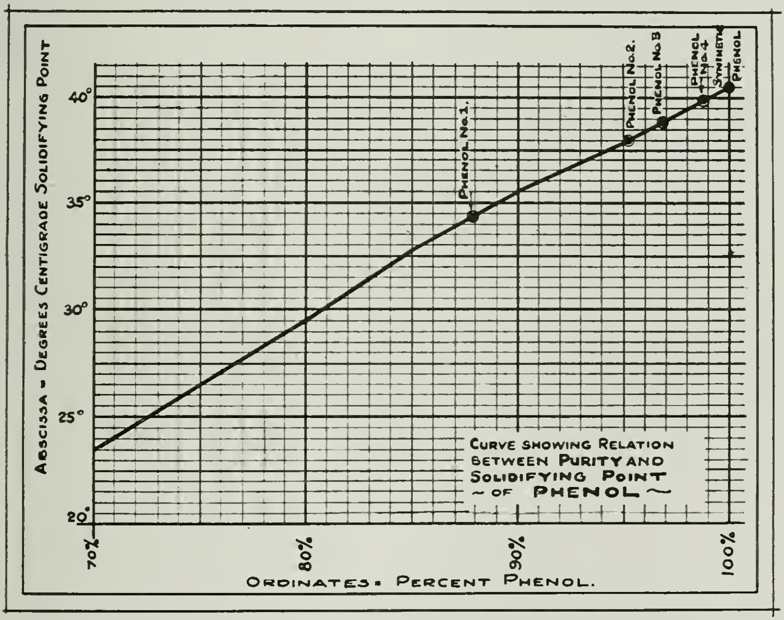
A curve was plotted, using percentages of phenol as ordinates and solidifying points as abscissæ. From this curve it was possible to deduce from a solidifying point of a dried phenol the degree of cresol contamination. Four phenols obtained from various sources in the open market were thus tested. They were dried before testing by heating about 100 grammes in a distilling bulb until the vapor temperature reached 170° C., experience having shown this to be completely adequate.

The results of these tests showed that the samples varied widely.

TABLE NO. 2.

Material.	Solidifying Point.	Cresols.
Phenol No. 1	34.4° C.	12.0%
Phenol No. 2	38.0°	4.8
Phenol No. 3	38.8°	3.4
Phenol No. 4	39.9°	1.1
Phenol synthetic	40.5°	0

FIG. 1.



These are also shown graphically in the curve accompanying this paper, the points at which the various phenols fell being clearly indicated (see Fig. 1).

Solutions of each of these, of approximately 5 per cent., were then made up in the following manner. About 50 grammes of dry substance were poured into a weighing bottle, stoppered, cooled and weighed to four places of decimals on a sensitive balance. The phenol was melted, then poured out into a litre flask, the weighing bottle being restoppered and reweighed. The litre flask was filled with water and carefully adjusted to the mark at 15.5° C.

In order to determine if analytical results would indicate the cresol contamination appreciably, samples of these solutions were sent to the Lederle Laboratories of New York City, and there assayed for phenol by the bromine titration method. The results of these analyses are as follows:

TABLE NO. 1.

Material.	Amount actually in solution.	Amount found by analysis.
Solution of phenol No. 1	5.34%	5.12%
Solution of phenol No. 2	5.14	5.12
Solution of phenol No. 3	5.43	5.44
Solution of phenol No. 4	5.20	5.22
Solution of phenol synthetic	5.41	5.47

It can readily be seen, even in the extreme case of No. 1, that the variation in test is one which would excite no suspicion and could very well, under ordinary circumstances, be attributed to experimental error. These solutions were then used in the bacteriological tests which follow.

A preliminary experiment with the particular strain of *Bacillus typhosus* (obtained through the courtesy of Dr. Park at the New York City Research Laboratories) established the fact that a 1 : 110 solution of synthetic phenol under Rideal-Walker normal conditions showed life up to 12½ minutes. This dilution was therefore taken in preparing standard solutions of the other four phenols to compare their relative germicidal values.

Five c.c. of each of these dilutions were transferred to a sterile test-tube by sterile pipettes. To each one of these tubes, at intervals of exactly thirty seconds, 5 drops of a 24 hours' culture of *B. typhosus* incubated at 37° C. in Rideal-Walker standard broth were added (the pipette used delivered drops of distilled water weighing approximately 0.05 gramme), and the half-minute interval was accurately continued whilst 30 broth tubes were inoculated with a single loopful of the medicated cultures. Throughout the experiment the temperature of the water bath in which the medication tubes were immersed was maintained at 15° C. Table No. 3 shows the results obtained after the 30 sub-culture tubes were incubated for 48 hours.

To show to what extent these various phenols would affect the coefficient of a disinfectant when used as standard controls, R.-W. determinations were made, taking the same high coefficient disinfectant as the postulant in each case. The results are seen in Tables Nos. 4, 5, 6, 7 and 8, whole multiples of the control dilution being taken in each case when preparing the dilutions of the postulant.

It is interesting, in this connection, to note that the results obtained agree very closely with the calculated theoretical figures, taking the coefficient of cresol as 3.0 (see Table No. 9). It is quite conceivable, had the experiments been conducted with *half* multiples when preparing the various dilutions for test, that the results might have agreed even more closely.

TABLE NO. 3.

B. TYPHOSUS, 24 HOURS' BROTH CULTURE AT 37° C.
Temperature of Water-bath 15° C.

Sample.	Dilutions.	Time culture exposed to action of disinfectant (minutes).						Sub-cultures.	
		2½	5	7½	10	12½	15	Period of incubation.	Temperature.
Phenol No. 1	1 : 110	X						48 hours	37° C.
Phenol No. 2	1 : 110	X	X	X	X			48 hours	37° C.
Phenol No. 3	1 : 110	X	X	X	X			48 hours	37° C.
Phenol No. 4	1 : 110	X	X	X	X	X		48 hours	37° C.
Phenol synthetic	1 : 110	X	X	X	X	X		48 hours	37° C.

TABLE NO. 4.

B. TYPHOSUS, 24 HOURS' BROTH CULTURE AT 37° C.
Room Temperature 15°–18° C.

Sample.	Dilutions.	Time culture exposed to action of disinfectant (minutes).						Sub-cultures.	
		2½	5	7½	10	12½	15	Period of incubation.	Temperature.
Pyxol	1 : 1650							48 hours	37° C.
Pyxol	1 : 1760	X						48 hours	37° C.
Pyxol	1 : 1870	X	X	X				48 hours	37° C.
Pyxol	1 : 1980	X	X	X	X			48 hours	37° C.
Phenol No. 1	1 : 110	X						48 hours	37° C.

∴ Rideal-Walker Coefficient $\frac{1760}{110} = 16.0$.

TABLE NO. 5.

B. TYPHOSUS, 24 HOURS' BROTH CULTURE AT 37° C.
Room Temperature 15°–18° C.

Sample.	Dilutions.	Time culture exposed to action of disinfectant (minutes).						Sub-cultures.	
		2½	5	7½	10	12½	15	Period of incubation.	Temperature.
Pyxol	1 : 1710	X						48 hours	37° C.
Pyxol	1 : 1805	X	X	X				48 hours	37° C.
Pyxol	1 : 1900	X	X	X	X			48 hours	37° C.
Pyxol	1 : 1995	X	X	X	X	X		48 hours	37° C.
Phenol No. 2	1 : 95	X	X					48 hours	37° C.

∴ Rideal-Walker Coefficient $\frac{1710}{95}$, $\frac{1805}{95}$ = 18.5 (average).

TABLE NO. 6.

B. TYPHOSUS, 24 HOURS' BROTH CULTURE AT 37° C.
Room Temperature 15°–18° C.

Sample.	Dilutions.	Time culture exposed to action of disinfectant (minutes).						Sub-cultures.	
		2½	5	7½	10	12½	15	Period of incubation.	Temperature.
Pyxol	1 : 1710	X						48 hours	37° C.
Pyxol	1 : 1805	X	X					48 hours	37° C.
Pyxol	1 : 1900	X	X	X	X			48 hours	37° C.
Pyxol	1 : 1995	X	X	X	X	X		48 hours	37° C.
Phenol No. 3	1 : 95	X	X					48 hours	37° C.

∴ Rideal-Walker Coefficient $\frac{1805}{95}$ = 19.0.

TABLE NO. 7.

B. TYPHOSUS, 24 HOURS' BROTH CULTURE AT 37° C.
Room Temperature 15°–18° C.

Sample.	Dilutions.	Time culture exposed to action of disinfectant (minutes).						Sub-cultures.	
		2½	5	7½	10	12½	15	Period of incubation.	Temperature.
Pyxol	1 : 1710	X						48 hours	37° C.
Pyxol	1 : 1800	X	X					48 hours	37° C.
Pyxol	1 : 1890	X	X	X				48 hours	37° C.
Pyxol	1 : 1980	X	X	X	X			48 hours	37° C.
Phenol No. 4	1 : 90	X	X					48 hours	37° C.

∴ Rideal-Walker Coefficient $\frac{1800}{90}$ = 20.0.

TABLE NO. 8.

B. TYPHOSUS, 24 HOURS' BROTH CULTURE AT 37° C.
Room Temperature 15°–18° C.

Sample.	Dilutions.	Time culture exposed to action of disinfectant (minutes).						Sub-cultures.	
		2½	5	7½	10	12½	15	Period of incubation.	Temperature.
Pyxol	1 : 1710							48 hours	37° C.
Pyxol	1 : 1800	X	X					48 hours	37° C.
Pyxol	1 : 1890	X	X	X				48 hours	37° C.
Pyxol	1 : 1980	X	X	X	X			48 hours	37° C.
Phenol synthetic	1 : 90	X	X					48 hours	37° C.

∴ Rideal-Walker Coefficient $\frac{1800}{90} = 20.0$.

TABLE NO. 9.

Material.	RIDEAL-WALKER coefficient found.	RIDEAL-WALKER coefficient calculated.
Phenol No. 1	16.0	16.12
Phenol No. 2	18.5	18.25
Phenol No. 3	19.0	18.56
Phenol No. 4	20.0	19.56
Phenol synthetic	20.0	20.00

GENERAL SUMMARY.

1. Phenol crystals are usually contaminated by cresols to such an extent as to make them unreliable for purposes of bactericidal control.

2. This impurity depresses the coefficient of a disinfectant.

3. The bromine titration is insufficient to insure the purity of phenol.

4. The purity must be first determined before the phenol is selected for use.

5. The purity should be established by determination of the solidifying point as outlined in the present paper.

6. The bromine titration should be used as a check on the gravimetric preparation of the stock 5 per cent. solution.

7. The authors present as a recommendation that no phenol showing a solidifying point of less that 40° C. be used for purposes of bactericidal control.

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[3] Anderson and McClintic, *Jour. Infect. Dis.*, vol. viii, No. 1, Jan., 1911, p. 1.
[4] Woodhead and Ponder, *Lancet*, 1909, ii, pp. 1454, 1516, 1612.
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[7] Sommerville and Walker, *San. Record*, Nov. 29, 1906; May 9, 1907; March 26, 1908.
[8] Koppeschar, *Z. anal Chem*, 1886, p. 233.
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[10] *Chem. Zeit. Rep.*, 1903, p. 86.

ABSTRACTS OF COMMUNICATED DISCUSSIONS.

My principal comment would be that the proposal to use only phenol having a solidifying point of not less than 40° C. appears superfluous, because of the fact that the United States Pharmacopœia, 8th Revision, official from September 1, 1905, recognized as a legal standard in such matters by Act of Congress of June 30, 1906, already provides that phenol shall have a solidifying point not lower than 40° C. In view of the foregoing, I would deem it the duty of all analysts, in making tests requiring the use of phenol as a standard substance, to adhere, as a matter of course, to a standard at least no lower than that set by the 8th Revision of the United States Pharmacopœia. I have myself tested various samples of phenol supplied in the ordinary course of laboratory routine, and have had no difficulty in obtaining samples complying with the U. S. P. requirement. I have further made inquiries from large manufacturing houses who use but do not manufacture phenol, and who inform me that they have no difficulty in obtaining phenol as above. I am, therefore, forced to think that the samples mentioned by Mr. Walker must have been of materials decidedly below the quality readily obtainable in the market.—DR. G. H. MEEKER, *Dean*, Dept. of Pharmaceutic Chemistry, The Medico-Chirurgical College, Philadelphia, Pa.

The paper suggests a new, or rather an additional, procedure to be followed in testing phenol as to its suitability for use in the determination of the Rideal-Walker coefficient.

All previous workers, it appears, used a chemical test for this purpose, the well-known Koppeschar volumetric method, using bromine. A *chemical* method is obviously unsuited for the determination of the presence of closely-related substances, as, for example, cresols.

The authors appear to be wise, therefore, in choosing a *physical* property for this purpose. They have chosen a freezing-point method, and it is interesting to note that the freezing point of a solution of cresol in phenol is a linear function of its phenol content and that this proportionality holds as far as 30 per cent. cresol (27 mol. per cent.), and perhaps farther.

It would be interesting to know whether other physical properties, such as specific gravity and refractive index, would also be useful in this connection.

It is very interesting to learn that the bactericidal power of a solution of cresol in phenol is an additive property, depending on relative proportions of the two, so that, knowing the Rideal-Walker coefficient with respect to a phenol which contains cresol, and knowing the proportion of cresol present as determined by the freezing-point method suggested here, the true Rideal-Walker coefficient (with respect to pure phenol) may be readily computed.—ABRAHAM HENWOOD, Department of Chemistry, Drexel Institute, Philadelphia.

Quantitative bacteriological methods have not been, as the authors state, developed to the extent that quantitative chemical methods have been, and one great reason for this is the comparatively few years since bacteriology has received the attention its importance warranted. Another reason why quantitative bacteriological methods have not been developed is the erroneous idea that all variations in experimental conditions influence greatly bacteriological results.

The common idea that the degree of susceptibility and immunity of test animals made accurate quantitative work impossible has largely been disproved. That this idea is erroneous has been well shown in the accuracy with which toxins and antitoxins may be tested. I have personally had a complete series of 250 Gm. guinea pigs live with a dose of 0.003 c.c. of filtered bouillon culture and all of another series die after a dose of 0.0035 c.c. of the same material. A still smaller difference is manifested with tetanus toxin. Dr. Anderson himself told me that he found an appreciable difference in the strength of the government standard of antitoxin because a minute piece of glass had accidentally fallen into the dried serum when he weighed it. The point I wish to make is that in all probability bacteriological methods are capable of being developed to a greater degree of accuracy than our present chemical methods.

There are several important factors in the determination of the carbolic coefficient besides the purity of phenol which render the results of this determination somewhat variable, and Anderson and McClintic (*Journal of Infectious Diseases*, vol. 8, No. 1) have determined the amount of variation due to several causes. It seems to me that these other factors usually have considerably more influence upon the results than a small amount of cresol in the phenol. I heartily approve of the use of chemically pure phenol being used as a standard, and do not desire to detract anything from the importance of this valuable contribution, but I do want to point out (1) that quantitative bacteriological methods, when perfected, will no doubt prove even more accurate than quantitative chemical methods; (2) that there are other factors in the determination of the Rideal-Walker coefficient that I believe will influence the results obtained to a much greater degree than the contamination of the standard phenol with 1 or 2 per cent. of cresol; (3) that the specifications proposed for the standard phenol should be rigidly observed, because it is one of the factors that will influence the final results.—DR. W. A. PEARSON, Professor of Chemistry, Hahnemann Medical College, Philadelphia.

I appreciate very much the contribution to exact technical method that you make therein, and the importance of requiring the utmost exactitude in all such testing. I am moved to ask you, however, if it be not possible for you to construct a formula for correcting results to a resolution factor that would be the correct one for the 40° melting phenol, even if a phenol of lower melting point were actually used in practice; and would thus permit a modification of your recommendation, embodied in No. 7 of your general summary, to, say, 40° "or corrected thereto."—DR. WILLIAM S. MAGILL, State Bacteriologist, Albany, N. Y.

ANSWER TO DISCUSSION.

Mr. Ainslie Walker, in reply, said:

Although Dr. Pearson has raised a point which deals with a question somewhat outside the scope of this paper, I gladly avail myself of the opportunity to reply. Dr. Pearson, although heartily approving of the use of chemically pure phenol, is of opinion that there are other factors in the determination of the Rideal-Walker coefficient that influence the results obtained to a much greater degree than contamination of the standard phenol, and that "Anderson and McClintic (*Journal of Infectious Diseases,* vol. 8, No. 1) have determined the amount of variation due to several causes."

I may say that both Dr. Rideal and myself were greatly surprised at Anderson and McClintic's arguments, as set forth in the paper referred to by Dr. Pearson. The only conclusion we could form was that these workers had overlooked certain important contributions to the literature of the subject.

For instance, in a paper published by Dr. Sommerville and myself in *Public Health* (the official organ of the Society of Medical Officers), March, 1906, we called attention to the fact that life in 2½ and 5 minutes, in the phenol control, was the desired result. And Dr. Rideal, in a paper which he read at the 14th International Congress for Hygiene and Demography, at Berlin, in September, 1907, again emphasized the fact. Yet in Anderson and McClintic's paper we read "the great objection to the method, however, and it is almost a vital one, is the latitude allowed in determining the coefficient. This point is strikingly brought out in the following tables." They then set out a table showing life in 2½ minutes only, in the postulant and control, and compare the ratio so obtained with that which they get from another table showing life up to 12½ minutes in the postulant and control!

Far from wishing to shelter behind these two references, I will go further, and say that later experience has proved that strictly comparable results are obtained even up to 7½ minutes.

Dr. Magill's suggestion is an excellent one, but, unfortunately, not practicable. If we were sure that the disturbing influence was due in all cases to the presence of pure cresol, we might suggest the addition of 1 per cent. to the found coefficient for each drop of 1° C. in the solidifying point of the phenol used as control: but, as we find in practice that the disturbing influence may be partly due to the presence of the next higher homologue of cresol, this suggestion cannot be put forward.

Mr. Weiss, in reply, said:

In regard to Dr. G. H. Meeker's comment that a proposal to use phenol having a solidifying point of not less than 40° C.

was superfluous, in view of the fact that the United States Pharmacopœia had already provided such a solidifying point as the lowest limit, I would say that evidently Doctor Meeker has not taken cognizance of a revision sheet of the Pharmacopœia, issued under date of June 1, 1907, in which the requirements for solidifying point of phenol were dropped to 39° C. This limit of the Pharmacopœia would permit the presence of 3 per cent. of cresol, which would lower the Rideal-Walker coefficient from a postulate twenty to at least nineteen. Therefore, although the Pharmacopœia requirements are probably stringent enough so far as phenol for medical purposes is concerned, yet it should not be taken as a standard for *pure* substances to be used in quantitative determinations, either chemical or bacteriological.

Mr. A. Henwood makes the suggestion that possibly specific gravity and refractive index would be useful in detecting the presence of cresols in phenol. I may say that, so far as specific gravity is concerned, this would be of little value, in view of the fact that the three isomeric cresols among themselves have quite varying specific gravities, and that, therefore, two mixtures of quite different degree of cresol contamination might, owing to the relative proportions of the cresols making up that contamination, have identical specific gravitites. So far as refractive index is concerned, I have never done any work on that point, and, therefore, am unable to form an opinion as to the value of such tests. In general, I would say, however, that a refractometer is not an instrument that is readily available in most laboratories, whereas an accurate thermometer should be, and as the solidifying-point method requires only an accurate thermometer to carry out, it is comparatively simple, and within the reach of all.

Artificial Tulle. A. M. AUTY. (*J. Soc. Dyers and Col.*, xxviii, 16.)—A cupro-ammoniacal solution of cellulose, made in the form of a stiff paste, is delivered into a reservoir, the inclined side of which forms a scraper delivering the paste into the hollows of an engraved cylinder revolving against the scraper. The cylinder passes through a coagulating solution, the cellulose (hydrate) being then drawn off as a continuous fabric over a suitable roller. The tulle is then washed, dried, and finished. Many designs, said to be technically impossible in weaving, may be obtained by this process of molding.

NOTES FROM THE BUREAU OF STANDARDS.

STANDARDIZATION OF GOVERNMENT SPECIFICATIONS FOR PORTLAND CEMENT.

In June, 1911, the Secretary of the Department of Commerce and Labor arranged, through the secretaries of the various departments, for a conference of Government engineers for the purpose of unifying the specifications for Portland cement used by the United States Government. At this conference a committee was appointed to consider existing specifications and to recommend a single specification for Portland cement to be used by all departments of the Government.

After an extended series of meetings of this committee, at which careful consideration was given to representative specifications for Portland cement, as well as to all available data on methods of tests, a tentative specification was developed, which was reported to the departmental conference at a general meeting held July 20, 1911.

In view of the desirability of agreement between the specifications in use by the public and those adopted by the Government, the committee was instructed by the conference to confer with representative consumers and manufacturers as well as the special committees of the national engineering societies more directly interested in the subject of cement specifications. As a result the tentative specifications first reported by the departmental committee were modified slightly, until substantial agreement was reached on practically all points except the methods of determining the normal consistency and time of setting, and the following specifications were unanimously adopted by the departmental conference at the meeting held February 13, 1912.

It was recognized that no specification can be considered final, but must be subject to revision from time to time as occasion requires, and provision will be made for such revision by the various Government departments, all of which have adopted the specification as recommended by the conference.

EXECUTIVE ORDER.

It is hereby ordered that all Portland cement that may hereafter be purchased by any department, bureau, office, or independent establishment of the Government, or that may be used in construction work connected with any of the aforesaid branches of the Government service, shall conform in every respect to the specification for Portland cement adopted by the Departmental Conference at the meeting held at the Bureau of Standards on February 13, 1912, and approved by the heads of the several departments (to be known as the United States Government Specification for Portland Cement): Provided, however, that such specification may be modified from time to time by any similar departmental conference, with the approval of the heads of the several departments.

WM. H. TAFT.

THE WHITE HOUSE,
April 30, 1912.

The National Bureau of Standards, in its general investigation of structural materials, is engaged, among other things, in the determination of the physical properties of concrete. At the suggestion of engineers and others, the Bureau of Standards is investigating the cause of cracking in concrete structures, where the necessity for expansion and contraction joints is questioned. For this purpose reference marks were placed last week on some of the typical old and new concrete work in Wayne County, Mich., also at Greenwich, Conn. Measurements will be taken from time to time during the summer and winter to determine the expansion or contraction in the concrete caused by temperature variations and the changes of volume which take place during the hardening of the concrete. Similar reference marks are being placed on the lock walls of the Panama Canal and various other structures, from which valuable information will be obtained.

The following circulars have just been sent to press by the bureau:

Circular No. 34.—The Relation of the Horsepower to the Kilowatt.

Circular No. 35.—The Melting Points of Chemical Elements.

Circular No. 36.—The Testing and Properties of Electrical Condensers.

Copies of these circulars may be obtained upon application to the Director.

FRANKLIN INSTITUTE

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, June 5, 1912.*)

Hall of the Institute,
Philadelphia, June 5, 1912.

Mr. Wilfred Lewis in the Chair.

The following reports were presented for final action:

No. 2507.—Squier's Multiplex Telephony. Cresson Medal. Adopted.

No. 2517.—Dietz's Multi-speed Shutter. Motion to recommend Scott Award adopted.

First Reading:

No. 2519.—Gibson's Metering Feed-water Heater. Advisory. Adopted.

R. B. Owens,
Secretary.

MEMBERSHIP NOTES.

Elections to Membership.

RESIDENT.

Mr. Geo. H. McFadden, Eighteenth and Spruce Streets, Philadelphia, Pa.
Mr. Raymond W. Tunnell, 15 North Fifth Street, Philadelphia, Pa.
Mr. Hermann Dannenbaum, care of National Ammonia Company, Frankford, Philadelphia.
Mr. Wistar E. Patterson, Electric Storage Battery Company, Nineteenth and Allegheny Avenue, Philadelphia, Pa.

NON-RESIDENT.

Mr. J. Steph. van der Lingen, Box 59, Kroonstad, O. F. S., Union of S. A.

ASSOCIATE.

Mr. John S. Nittrouer, 417 Chelten Avenue, Ashbourne, Pa.

Changes of Address.

Mr. J. B. Rumbough, 49 Zillicoa Street, Asheville, N. C.
Dr. M. G. Lloyd, 608 Dearborn Street, Room 1350, Chicago, Ill.
Mr. Harold C. Heilman, 1932 Race Street, Philadelphia, Pa.
Prof. Harris J. Ryan, Stanford University, California.
Mr. Edw. N. Dickerson, 141 Broadway, New York City.
Dr. Charles L. Reese, DuPont Building, Wilmington, Del.

NECROLOGY.

Mr. John T. Kille, 1822 Green Street, Philadelphia, Pa.

LIBRARY NOTES.

Purchases.

American Institute of Chemical Engineers Transactions. 3 vols. 1909–1911.
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HOBART, H. M.—The Design of Static Transformers. 1911.
HURST, C.—Hints on Steam Engine Design. 1905.
KENNELLY, A. E.—The Application of Hyperbolic Functions to Electrical Engineering Problems. 1912.
GEAR, H. B., and P. F. WILLIAMS.—Electric Central Station Distribution Systems. 1911.
MORSE, H. W.—Storage Batteries. 1912.
BELL, L.—The Art of Illumination. 1912.
HOBART, H. M.—Electric Trains. 1910.
KEMP, J. F.—A Handbook of Rocks. 1911.
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JOHNSON, J. H.—Arc Lamps and Acessory Apparatus. 1911.
JORISSEN, W. P., and L. T. REICHER.—J. H. Van't Hoff's Amsterdamer Periods. 1912.
CANDOLLE, A. DE.—Histoire des Sciences et des Savants. 1885.
SCHWALBE, C. G.—Die Chemie der Cellulose. 1911.
DEVEY, R. G.—Mill and Factory Wiring. 1911.
MOLDENHAUER, W.—Chemisch-technisches Praktikum. 1911.
JONSTORFF, H. J. v.—Das Eisenhüttenwesen. 1912.
LUNGE, G.—The Manufacture of Sulphuric Acid and Alkali. Vol. 3. 1911.
THORPE, E.—A Dictionary of Applied Chemistry. 1912.
VILLAMIL, R. DE.—A, B, C of Hydrodynamics. 1912.
NOBLE, H.—Fabrication de l'acier. 1905.
LAVAL, C. G. DE.—Centrifugal Pumping Machinery. 1912.
BELLASIS, E. S.—The Influence Exercised by Ships on One Another. 1911.

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Wisconsin, State Historical Society, Proceedings of the 59th Annual Meeting, 1911. Madison, 1912. (From the Society.)
Gurley's Handbook of Weights and Measures for the Use of Sealers, 4th edition, 1912. Troy, 1912. (From W. and L. E. Gurley.)
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Canada Department of Mines, Annual Report on the Mineral Production of Canada, 1910. Ottawa, 1912. (From the Mines Branch.)

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PUBLICATIONS RECEIVED.

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College Engineering Notebook for Classes in Technical Schools and Colleges. Designed and arranged by Robert E. Moritz, Professor of Mathematics in the University of Washington. 17 pages of formulæ and tables and blank pages for notes. Quarto. Boston, Ginn & Co., no date.

Industrial Organic Chemistry, adapted for the use of manufacturers, chemists and all interested in the utilization of organic materials in the industrial arts, by Samuel P. Sadtler, Ph.D., LL.D. Fourth edition, revised, enlarged and reset. 601 pages, illustrations, 8vo. Philadelphia, J. B. Lippincott Co., 1912. Price, $5.

Die elektrolytische Alkalichloridzerlegung mit starren Metallkathoden von Dr. Jean Billiter. I Teil, 284 pages, illustrations, 8vo. Halle-a.-S., Wilhelm Knapp, 1912. Price, 16.50 marks.

Analyst's Laboratory Companion: a collection of tables and data for the use of public and general analysts, agricultural, brewers' and works' chemists, and students; together with numerous examples of chemical calculations and concise descriptions of several analytical processes, by Alfred E. Johnson, B.Sc.(Lond.). 164 pages. 12mo. Philadelphia, P. Blakiston's Son & Co., 1912. Price, $2.

Developers and Development. A practical survey of the principal developers and their characteristic points: with reliable formulæ and instructions for their use in negative making. 64 pages, 12mo. New York, Tennant & Ward, no date. Price, 25 cents.

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Bromide Printing and Enlarging. A practical guide to the making of bromide prints by contact and bromide enlarging by daylight and artificial light, with the toning of bromide prints and enlargements. 63 pages, illustrations, 12mo. New York, Tennant & Ward, no date. Price, 25 cents.

Soren Hjorth, Inventor of the Dynamo-electric Principle, by Sigurd Smith. Published by "Elektroteknisk Forening" at the expense of the Carlsberg Foundation. 28 pages, illustrations, plates, 8vo. Kobenhavn, J. Jorgensen & Co., 1912.

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CURRENT TOPICS.

Setting Properties of Portland Cement. G. Hentschel. (*Tonind. Zeit.*, xxxvi, 557.)—The change in cement from slow to quick setting is due to the presence of alkali carbonates, which, as positive catalysts, have an accelerating influence on the setting process. The addition of only 0.01 per cent. of sodium carbonate in one case reduced the time of setting from about 6½ hours to 20 minutes. On the other hand, the addition of varying amounts of calcium sulphate retards the time of setting, and the cements remain slow setting. The power of catalysts should be determined by comparative experiments. Sodium and potassium carbonates exert an extraordinarily strong positive effect, while calcium sulphate possesses a relatively smaller negative catalytic effect. The positive effect is much more marked when the cements are finely ground. By burning, any alkali present in the raw materials is converted into an alkaline silicate, which has no effect on the setting, but by exposure to the air these silicates, after grinding the clinker, are slowly decomposed into silicic acid and carbonates, especially under the influence of heat. Experiments on a given cement showed that the time of setting was accelerated by heat, with free access of air, but when carbon dioxide was excluded the time of setting was unchanged after heating the cement on a water-bath for an hour. The pronounced effect of carbon dioxide and heat explains why rotary-kiln cement changes much more easily than cement burned in other kilns, and often leaves the mill in a quick-setting condition. Rotary-kiln clinker tends to be hard, and is consequently heated to a considerable extent by grinding—as high as 87° C. sometimes—and on cold days there is less danger of producing a quick-setting cement through the grinding. The change in the time of setting produced by calcium sulphate is independent of the presence or absence of water of crystallization in the calcium sulphate.

A New German Dirigible Airship. Anon. (*Rev. Sci.*, xv, 1470.)—The innumerable accidents to the Zeppelin airships have not discouraged the Germans in their determination to produce larger and larger airships. The Siemens-Schuckert shops are now constructing a dirigible 118 metres long, and of 13.2 m. maximum diameter, with a capacity of 13,000 cubic metres. This envelope is divided into four compartments by three impermeable partitions. Each of the three forward compartments contains an air balloon; the first compartment gives the dirigible's head the appearance of an almost perfect hemisphere, and this is reinforced by a "helmet" of ten layers of caoutchouced linen. The envelope is of the flexible type. The fourth compartment, kept at the normal atmospheric pressure, is intended to receive the gas which has escaped from the other three through the safety-valves. It is a very elongated cone in shape. The keel, 80 metres long, is a steel frame in which a man can walk around. It carries the reservoirs of water and of gasoline, also the machinery for filling the balloons (2 motors of 24 horsepower) and for working the safety-valves. Its end is the guiding rudder, 5 planes of 4 x 1.4 metres. Three cars are suspended from the keel, which communicate with each other by a mechanical telegraph. The guiding wings are in the middle car. Each of the other two carries a Daimler motor of 125 horsepower, two depressing rudders, two lateral screws, each with two blades, 3 metres in diameter, running at 700 revolutions, and one axial screw with four blades, running at 750 revolutions.

Action of Nitrogen on Magnesium. MATIGNON and LASSIEUR. (*Bull. Soc. Chim.*, ii, 262.)—Magnesium nitride may be obtained in crystalline form by heating the metal in a crucible almost completely closed and placed in a muffle at a temperature high enough for volatilization. The magnesium vapor combines slowly with the nitrogen of the air, forming the crystalline nitride.

Sintering and Fritting. L. PODSZUS. (*Arch. Physik. Chem. d. Glases u. d. keram. Massen.*, I, 2.)—Even brittle substances soften near their melting point, as is shown by the deformation of thin rods of pure alumina, thoria, zirconia, silica, and magnesia when these are heated below the melting point. Sintering can be greatly influenced by alteration of the surface energy. Tubes of alumina, thoria, silica, magnesia, or zirconia showed much greater sintering when a mercury vapor arc was produced in them during the heating than when the exhausted tubes were heated. The sintering of the oxides mentioned is promoted by the addition of boric acid, which exerts a solvent action.

Loss in the Manufacture of Salt-Glazed Stoneware. E. BERDEL. (*Sprechsaal,* xlv, 161.)—A loss of 33 per cent. was incurred in the manufacture of beer tankards through heavy deposits of undecomposed salt on the ware. These deposits contained iron, but the original salt (though denatured by pyridine to pass duty-free) contained less than 0.1 per cent. of iron oxide. Nor was the fault in the body, as a white porcelain mixing gave a similar loss. The loss was ultimately traced to some sand used in making the gear, which contained iron hydroxide. In the fire the volatilized salt caused iron chloride to drip on the ware below each piece of gear, thereby preventing the chemical action of salt-glazing. A new source of sand obviated the loss.

Action of Pure Distilled Water, with or without Electrolytes, on Metals. M. TRAUBE-MENGARINI and A. SCALA. (*Z. Chem. Ind. Kol.*, x, 113.)—Experiments on the action of water, under different conditions, on the metals iron, zinc, copper, nickel, tin, and lead are described, and in all cases the formation of colloidal solutions of the metals was observed, as shown especially by ultramicroscopic examination.

Deflocculation of Artificial Graphite. E. G. ACHESON. (*Eng. News.*, lxvi, 677.)—Clay is deflocculated by agitation in an aqueous solution of tannin, then sodium chloride is added, which precipitates or flocculates the clay. To obtain deflocculated graphite, artificial graphite is ground till it will pass a sieve with 40,000 meshes per square inch, and then is macerated with a solution of tannin (about 5 per cent. of the weight of the graphite) or with extracts of straw or infusions of tea, etc. Deflocculated graphite is flocculated by the addition of acid. The following substances can be deflocculated: artificial graphite, natural graphite, amorphous silica and alumina, lampblack, and siloxicon (SiC_2O). Organic washes which will produce deflocculation are solutions of tannin, or of organic substances containing tannin solutions of the gum of the peach and cherry tree, extracts from straw or grass or of barn-yard offal. Electrolytes are flocculating agents. Recent microscopic examination shows that deflocculated graphite, as in oil-dag or aqua-dag, is a true colloid. Acheson thinks that the subdivision of the particles stops short only of the molecules.

Chemical Action of Penetrating Radium Rays. A. KAILAN. (*Monats. Chem.*, xxxiii, 71.)—Potassium iodide, both in neutral and acid solution, is decomposed more rapidly than sodium iodide by penetrating radium rays in the absence of light. The rate of decomposition is increased by increasing the concentration of the salt (though in a less degree), and by the addition of small quantities of acid; it also increases with the strength of the radium preparation, though more slowly, as observed in the decomposition of hydrogen peroxide. With neutral, normal potassium iodide solution, the decomposition at 25° C. was somewhat smaller than at 12° C. and 7° C. The decomposition is considered to be principally due to the direct action of the radium rays on the non-dissociated iodide molecule.

Coating for Iron and Steel. ANON. (*Amer. Mach.*, xxxvi, 13, 508.)—A new process of amalgamating a zinc alloy with iron and steel, called "Lohmannizing," has recently been patented by the Brier Hill Steel Company, Youngstown, Ohio. The process is as follows: The base metal is so treated as to produce a perfect fusion between the protective alloy and the base sheet; the alloy penetrates the minute pores and cavities of the sheet, becoming incorporated with it. Photo-micrographs of cross-sections of Lohmannized sheets show that there is a gradual shading off from the alloy to the base, indicating that a second alloy is formed between the original alloy and the protected metal. The thin exterior coating of alloy may crack, but, on account of the alloy formed with the sheet, this will have no effect upon the non-corrosive qualities of the Lohmann metal.

Properties of White Metal. ANON. (*Amer. Mach.*, xxxvi, 13, 535.)—Tests made at the Royal Laboratory at Gross-Lichterfelde-West, to determine the effect of repeated melting, heating, and cooling on the chemical composition and mechanical properties of bearing-metal alloys, show that repeated melting does not make substantial changes in the chemical composition of white metal. The percentage of copper in the alloy increases by about 0.2 of 1 per cent. for each melting, but the ratio of tin and antimony remains the same, although the absolute percentage of these metals in the alloys decreases by about 1.4 per cent. after five meltings. Further, it was found that when white metal is heated and then cooled its mechanical strength is increased by rapid cooling and decreased by slow cooling; slowly-cooled metal is about 10 per cent. weaker.

Natural Gas. ANON. (*Amer. Mach.*, xxxvi, 14,547.)—In a bulletin recently published by the Bureau of Mines on "Liquefied Products from Natural Gas," it is pointed out that by fractionating natural gas, either during or after liquefaction, four commercial products can be obtained. These are: (1) The common natural gas of commerce; (2) the semi-liquid product, known as the new "wild" product, which should be used only as a liquefied gas, and should be kept in high-pressure steel containers only; (3) the light liquid product, or light gasoline, used for blending with heavy naphthas; and (4) the heavy liquid product, or ordinary high-grade gasoline. The possibility of handling the second product, the semi-liquid or "wild" product, in the same manner as Pintsch and Blau gases are handled, manifestly opens a new field of comparatively great importance in the natural-gas industry.

Blackening Small Iron Parts. ANON. (*Amer. Mach.*, xxxvi, 16, 631.)—According to *Metalltechnic,* small iron parts are blackened by means of two baths. The first is made by dissolving 10 parts of copperas in 20 parts water, and 15 parts of tin chloride in 30 parts water, and mixing the two; then dilute with about 400 parts water. The second bath is composed of 3¼ pounds of sodium thiosulphate, ⅙ pound hydrochloric acid, and 2 1/5 pounds water. First the sodium thiosulphate is dissolved in hot water, and the hydrochloric acid should not be added till the bath is to be used.

On adding the acid a yellow precipitate of sulphur is formed, which should be removed from the solution by filtering through muslin. The articles are immersed in the first bath for 10 seconds, rinsed with water, and immediately placed in the second bath for three minutes.

A Satisfactory Method of Adding Aluminum to Brass. (*Brass World,* viii, 4, 115.)—The good effect of aluminum in brass castings has been thoroughly demonstrated; it makes the castings sounder, remarkably free from pin-holes, it runs sharper, and the castings come out of the sand cleaner. Usually the aluminum is added to the brass just before pouring. The amount used is so small, however, that it is difficult to alloy it with the brass; it frequently merely floats on the top of the melted metal, and often causes the brass to "flare" and so wastes spelter. The best method of adding it is to first make an alloy of zinc 3 parts, aluminum 1 part, then add this to the brass. Of course, 4 parts of this alloy equals 1 part of aluminum. This alloy is frequently called "aluminized zinc." For ordinary yellow brass work from 2 to 3 ounces of aluminum are used, which is equivalent to 8 to 12 ounces of "aluminized zinc." If more is added, the brass becomes harder and is apt to shrink considerably.

Molten Iron Not Magnetic. (*Brass World,* viii, 4, 126.)—When red hot, iron is not magnetic, but becomes so when it falls to a black heat. Hence, iron can not be removed from molten metals by means of a magnet.

Production of Sound Steel Ingots. SIR ROBERT A. HADFIELD. (*Eng. Mag.,* xliii, 1, 95.)—Numerous devices, both simple and complicated, have been devised for producing sound steel free from all defects, which have given more or less satisfactory results. Generally, however, the heavy cost of the necessary apparatus has barred it from extensive use. The Hadfield process consists in heating the metal in the upper part of an ingot or other mold and maintaining it in a liquid condition by the combustion in contact therewith, or in close proximity thereto, during the cooling and shrinkage of the metal in the lower part of the mold, of solid fuel —*e.g.,* charcoal—by means of a blast of compressed air which is caused to impinge on the fuel while the fuel is directly or indirectly supported by the metal below; also the interposition of a layer of fusible material, such as iron slag, which has no injurious action on the metal, between the metal and the fuel.

The cost of carrying out the method is trifling compared with the large saving gained in reducing loss and waste material. The quality of the product is improved, in that there is less discard and the material is sounder. The system can be applied equally well to small or large ingots. On a large output the saving is estimated at from $2 to $3 per ton. The ingots obtained are free from blowholes, piping, and segregation. About 93 per cent. of the ingot may be utilized for commercial purposes. In mild steel the loss is about 8.8 per cent., and in ordinary steel about 7.9 per cent., the rest of the ingot representing salable and serviceable billets.

Zinc Alloys for Galvanizing. L. SÄNGER. (*Zeit. Angew. Chemie,* 2380.)—Alloys containing 96 to 99.5 per cent. of zinc, 0.5 to 1.5 lead, 0.1 to 0.5 iron, 0.01 to 0.1 copper, 0.5 to 2 tin, 0.1 to 0.5 carbon, 0.05 to 0.5 aluminum, are preferable to rolled zinc as anodes, because they cohere even when reduced almost to paper thickness. They are made in the shape of plates and rods, and other forms, from new and old metals.

Propeller Erosion. (*Engineering,* xciii, 33.)—Manganese bronze temporarily solved the problem of preventing corrosion and erosion observed in the earlier type of steel propellers. The introduction of turbines caused the reappearance of erosion often in a serious form; for example, a blade of a wing propeller of the Mauretania eroded to a depth of 2 inches over an area of 3 or 4 square feet in a short time. O. Silberrad's researches have shown that, unlike corrosion, erosion is not selective as between copper and zinc, but that it depends on the structure of the alloy, removing the eutectic and leaving the mixed crystals. As a result of numerous tests an alloy, known as "Turbodium" has been produced. It has a tensile strength of 38 to 40 tons per square inch, a yield point of 18 to 19 tons, with an elongation of 15 per cent. on 2 inches. Under the laboratory standard erosion test, it showed an endurance of 140 hours, as against 24.7 hours for the ordinary high-tension bronze. This result has been confirmed by actual trials lasting from six months to three years on various turbine-driven vessels, none of whose propellers show any signs of erosion up to the present.

Boston Elevated Railway. (*Elect. Rly. Journ.,* xxxviii, 1313.)—In this article there is given a complete account of the system of power generation and distribution of the Boston Elevated Railway. Owing to alterations and additions the whole system has become very complicated, and the original paper should be referred to, in order to arrive at a full comprehension of the subject. The company has a total rated direct-current generating capacity of 51,183 kilowatts, but this will shortly be raised to 64,700 kilowatts by the purchase of power from the Boston Edison Company. This power will be converted from alternate to direct current for the use of the railway. The whole system is in process of being rearranged and simplified.

Electrolytic Oxygen in Cyanide Solutions. T. H. Aldrich, Jr. (*Amer. Inst. Mining Eng., Bull.* lxii, p. 177.)—Experiments made in the laboratory and on the manufacturing scale with 25,000 tons of ore in the factory prove that the extraction of gold and silver is much more complete, especially when sulphides, graphite, grease, and other reducing agents are present, and that much cyanide is saved, when the cyanide is electrolyzed by continuous or alternating currents, with lead electrodes on 110 volt circuits. Eighteen lead plates, ⅛ inch thick, 6 inches square, connected in series, have been in continuous service for over two years. Lead electrodes are more serviceable than those of iron or carbon.

Steel and Wrought-Iron Pipe. Anon. (*Amer. Mach.,* xxxvi, 16, 638.)—Although steel pipe is more extensively used for general purposes around the steam plant than wrought-iron pipe, many engineers are unable to tell by the appearance whether a piece of new pipe is iron or steel, and yet there is a marked distinction. Steel pipe appears smoother, and whatever scale it may bear stands out in small blisters, which reveal a smooth and usually white surface beneath when scraped away. Iron pipe is generally quite rough, often lacks the even symmetry of steel pipe, and its scale lies in heavy flakes. Steel pipe will stand much flattening without fracture, which iron pipe will not. Iron pipe shows a coarse, jagged fracture, on account of the laminated and fibrous structure of the metal, while fractured steel pipe shows a fine crystalline grain.

Action of the Ultra-violet Rays on Sodium Hyposulphite. Louis Marmier. (*Mon. Sci.,* ii, 843, 212.)—The ultra-violet rays from a Westinghouse lamp of about 240 watts were directed on solutions of sodium hyposulphite of different concentrations, placed 6 to 8 cm. from the lamp. The volume varied from 15 c.c. to 200c.c. Under these conditions, in solutions containing less than 6 grammes per litre of sodium hyposulphite, there was formed hydrosulphite after five minutes' exposure, and at the same time sulphur was deposited. Further, under the influence of the ultra-violet rays the hydrosulphite itself is decomposed and only a trace remains after an exposure of 75 minutes. The solution then consists chiefly of sodium sulphite. With concentrations higher than 6 grammes of sodium hyposulphite per litre, no formation of hydrosulphite could be detected, no matter how long the exposure, nor what quantity of liquid was exposed.

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THE ELECTRO-PNEUMATIC BRAKE SYSTEM FOR STEAM ROAD SERVICE.[1]

BY

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IN a paper read before the members of this Institute some eighteen months ago, the speaker had something to say regarding air brakes. In this the importance of the air brake in general was given prominence. This evening an attempt will be made to impress upon you the great value of applying electricity as the means of operating the pneumatic or compressed-air brake, the effect of which is obtained by transforming the fluid pressure into a mechanical force, the energy of the vehicle being dissipated by friction between the brake shoes and the wheels of the vehicle.

It has long been known that electricity could add to the flexibility and efficiency of a compressed-air brake, but, so far as steam road equipment is concerned, there are four chief reasons why it has not heretofore been employed for this purpose:

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[1] Read by Mr. Walter V. Turner at the meeting of the Mechanical and Engineering Section held Thursday, April 4, 1912.

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First.—Electric current has not been available without special provision being made for it.

Second.—We have not had sufficient knowledge or material at hand to insure a reliable current and connections.

Third.—Because the present air brake has been sufficiently flexible and near enough to being simultaneous for the conditions up to quite recently.

Fourth.—That the pneumatic brake had not been brought to such a degree of perfection as would warrant the application of electricity to it.

(1) Now, however, current is available on practically all the steam trunk lines, as well as on electric railway and steam road electrifications, as nearly all first-class trains are lighted by electricity.

(2) Now the art has developed into a science, in that reliable information and data are at hand with which to make practicable applications, and jumper connections have been brought to such a state of simplicity and reliability that there is no longer need for fear in these respects.

(3) As affecting the action and results of the operation of the pneumatic brake, at least two serious changes in conditions have occurred:

First.—Heavier vehicles.

Second.—Longer trains.

In addition to this, time has become much more important than heretofore because, (1) by congestion of traffic, particularly adjacent to large cities, and (2) because the time lapse as a factor in controlling trains composed of heavy vehicles with the pneumatic brake has become quite serious.

The time element in the brake operation is very important in two ways. In one, it is very necessary, and in the other very undesirable. First, for service operations a time interval is necessary in some steps of the operation; for instance, while it is important that the brake commences to apply on each vehicle of a train simultaneously, it is equally important that the development of the force be obtained gradually, and both these for the same reason, namely, the elimination of damaging shocks and discomforting surges to or in the train. The simultaneous application prevents the slack from first running in and then out, and so on; while the slow rise of cylinder pressure prevents a too sudden and rapid change of motion,—that is, deceleration, with its consequent disagreeable effect upon the passengers. In emergencies the time element is very undesirable, as to stop is then the only consideration, the requirement being that the consequences be less disastrous than if the accident had not been avoided.

With regard to time, so far as traffic is concerned, every second saved between stations means an increase in the number of passengers it is possible to carry on the same track, as well as a reduction in the schedule time, more trains possible in the same time, and consequently greater realization of the object of running a railroad.

With regard to the time affecting results of pneumatic brake operation, this is manifested with long trains in the increase of time necessary to get the brake applied, and by shocks and stresses, due to the different designs of brake apparatus, or force at the front and rear of the train, at the same instant, and the more rapidly it is attempted to apply the brakes (when rapidity does not include simultaneous action) the greater will be the shocks and stresses. Moreover, when passenger rolling stock has been brought to its present state or condition for the comfort of travellers, any shortcomings, or lack of improvements in this respect, stand out very prominently by contrast, and this is particularly true of what is probably the only remaining two improvements to be made in modern trains, namely, the discomforts produced by the starting and stopping of these trains.

The application of electric current to the brake will not only eliminate the shocks and surges that occur with even the present slow service rate of brake application, but will permit of the application being made more rapidly throughout the train as a whole; thus, as above mentioned, being the equivalent of much more efficient motive power. This will be understood when it is considered that a train in motion is, in effect, a power plant, having a potential the utilization of which can be spread over many minutes, on the one hand, or condensed into a few seconds, on the other. That is, the train may be *permitted* to dissipate its energy in minutes or *compelled* to do it in seconds. Another way to look at this is that a train in motion with the power cut off is the waste product of the power-house (and usually most of it goes to waste, since it is not utilized to save time), and to-day it is to the heretofore waste product, turned into by-product, that many businesses owe their melon feasts.

With regard to the fourth proposition or assertion, namely, that the pneumatic brake has not until recently reached such a stage as would warrant its being actuated electrically, we may say that electricity would not in any sense add to the braking force, its purpose being to produce simultaneous operation; the application of the brake, in other respects, being identical with the ordinary pneumatic operations. The chief purpose in adding electricity to a pneumatic brake is to instantly transmit the intent of the engineer or operator to each vehicle of the train, thus eliminating the time element and, other things being equal, all shocks and stresses, both in service and emergency, and, in emergency, to shorten the stop somewhat by producing instantaneous application of the brakes on all vehicles in the train.

In the last year or two vehicles have become so large and heavy and trains so long because of large locomotives that the time element between the application and release of the brake from the engine to the last car has become a quite serious factor, since it permits the slack to run in or out, as the case may be, producing discomforting and sometimes dangerous shocks. Operating the service brakes electrically under such conditions then will eliminate this, while, in emergency, it will serve the twofold purpose of preventing shocks and shortening the stops. The retarding force, it must be understood, comes solely from the pneumatic portion of the brake, and until such a brake is installed that will produce the maximum emergency retardation desired or permissible, actuating the brake electrically will not only be a very expensive way to seek improvement, but will be far inferior in results to what could be done pneumatically.

Hereinafter we expect to have more to say on this phase of the matter and to illustrate it by graphic charts; therefore, it may be sufficient to state here that adding electric operation to the old brake, while it will improve matters here wonderfully so far as comfort is concerned, yet it will not compare with what can be done with the strictly pneumatic brake in the matter of stopping force. As the pneumatic brake is now sufficiently developed to warrant the application of electric control and transmission, it reduces to simply a question of expense and wisdom.

Before going into the design of the electro-pneumatic brake, it may be well to show some of its advantageous features and to emphasize the importance of improving the pneumatic brake to its highest degree, before adding electric features, by showing a few curves illustrative of the characteristics of the various improvements or changes in results.

The various curves to follow show comparative performances of service and emergency operation. The advantages of the electro-pneumatic equipment over the strictly pneumatic equipment are clearly shown in Figs. 1, 2, and 3.

The results shown on these curves represent service and emergency stops made from a speed of 40 miles per hour with a 10-car train equipped with the electro-pneumatic brake and an 8-car train equipped with the old-style equipment (P. M.).

Curves 1 and 2 on each figure illustrate the relative decrease in speed as the stop is approached, and curves 3 and 4 show the relative percentage of braking power developed.

The full line curves in each case represent the improved equipment, and the dotted line curves the old equipment.

Fig. 1 represents comparative stops made with a typical service application of the brakes in each case. These curves are plotted on a *time* base to permit of more directly representing the *time saved* and *economy factor* of the electro-pneumatic equipment as compared with the old pneumatic equipment. It will be seen that with the average manipulation, characteristic of the two types of equipment, there is a saving of 20 seconds in the time of stop, in favor of the electro-pneumatic equipment.

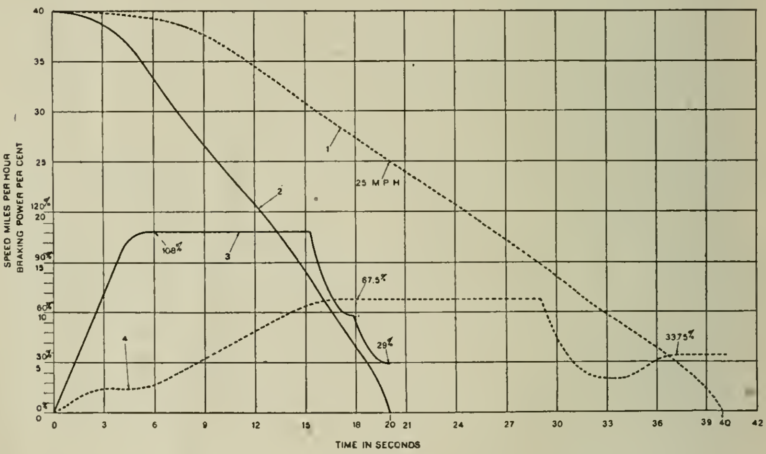
It will be evident that this shortening of the time of the stop is due to the fact that a *higher braking power* is obtained in a *shorter time,* and that the service action is started *simultaneously* on each car, as compared with serial action with the old pneumatic equipment.

This high percentage of braking power is permissible with the electro-pneumatic equipment by reason of the great flexibility of this equipment: that is, the simultaneous action permits of a high braking force at the start, while the speed is high, and by means of the graduated release feature the braking force can be gradually reduced as the speed of the train decreases.

With the old pneumatic equipment not having the graduated release feature the serial action in applying the brake, required different manipulations and would not permit of the use of high braking force if smoothness of stop was to be considered.

The maximum braking power with the new equipment (as shown by Curve No. 3), 108 per cent., was obtained in about 4½ seconds, and was retained for about 11 seconds longer, or until the speed of the train had been reduced to about 14 miles per hour, after which the brake was graduated off, the train coming to a stop, with the braking power reduced to 29 per cent. This curve may then be considered as a typical braking power curve showing the graduated release stop.

Fig. 1.



The maximum braking power with the old equipment, (as shown by Curve No. 4), 67½ per cent., was obtained after a lapse of 16 seconds and was retained for about 13 seconds longer, or until the speed of the train was reduced to about 14 miles per hour, at which time the brake valve was moved to release and back to lap, and then a second application was made, the train coming to a stop with the braking power about 33¾ per cent. This curve may then be considered a typical braking power curve showing the usual two-application stop, which is the nearest approach to the graduated release possible with the old equipment.

It will be noted that at the *time* the 10-car (electro-pneumatic) train has come to a stop, the 8-car (old equipment) train is still moving at a speed of 25 miles per hour (62½ per cent. of its initial speed), with about 39 per cent. of its original energy still remaining to be overcome before it can be brought to a standstill.

This shortening in the time of stop makes possible—higher speeds and shorter schedules, with consequent increased traffic capacity with the same number of cars and power consumption; or the *same* traffic capacity with *fewer cars;* or the same average speeds, schedules, and traffic capacity with *less* power consumption, since the power may be shut off sooner and the train allowed to drift or coast for 11 seconds (645 feet) before applying the brakes to make the stop at the same point.

To further show the difference in the two brake equipments, it is only necessary to mention that if two trains were started on parallel tracks at the same station and both attained the maximum speed, the train equipped with the electro-pneumatic brake would have reached the next station, stopped, discharged passengers, taken on passengers, and be started again before the train equipped with the old brake would have made its stop at the same point.

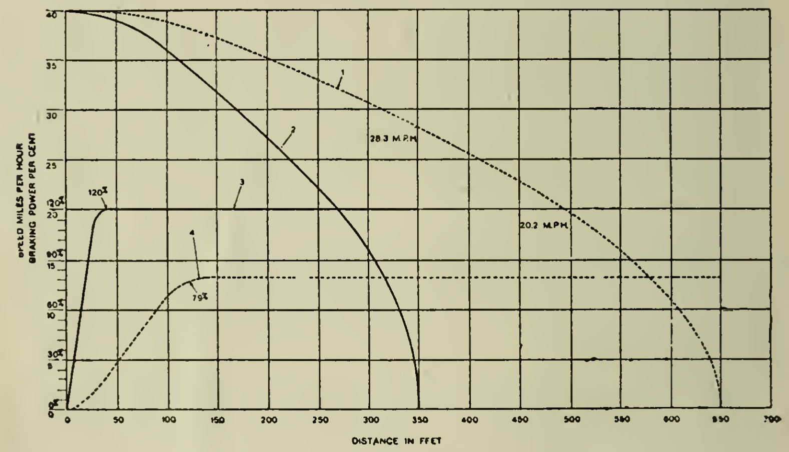
Even with this possibility of making service stops in a much shorter time, and thus increasing the traffic capacity of the system, there still remains the necessity of keeping the signals spaced the same distance as before, unless the emergency features of the brake are improved as well as the service.

But with the emergency brake improved, and the ability to stop the train in a much shorter distance, as shown by the curves on Fig. 3, it is possible to decrease the distance between signals and still maintain even greater safety than before.

It is possible then to not only run on a much less headway, and in some cases double the number of trains operating over the road, but also longer trains may be operated, since, by the simultaneous and uniform action of the brakes, shocks and stresses are reduced to a minimum, thereby permitting a greater number of passengers to be carried without discomfort, because of the greater number of cars per train and the smooth action of the brake.

Fig. 2 represents comparative stops made with an emergency application of the brakes in each case. These curves are plotted on a *distance* base to compare the *length of stop* and relative *safety factor* of the two equipments. It will be seen that the stop with the train having the electro-pneumatic equipment is made in a much shorter distance and less time than that with the old equipment. At the *350 foot mark* where the electro-pneumatic train stopped, the other is moving at a speed of 28.3 miles per hour (71 per cent. of its initial speed), with 50 per cent. of its original energy still remaining to be overcome before the train comes to a standstill. At the *time* the electro-pneumatic train stopped, the old equipment train has run 140 feet farther and is still moving at a speed of 20.2 miles per hour, representing 25.5 per cent. of its original energy.

Fig. 2.



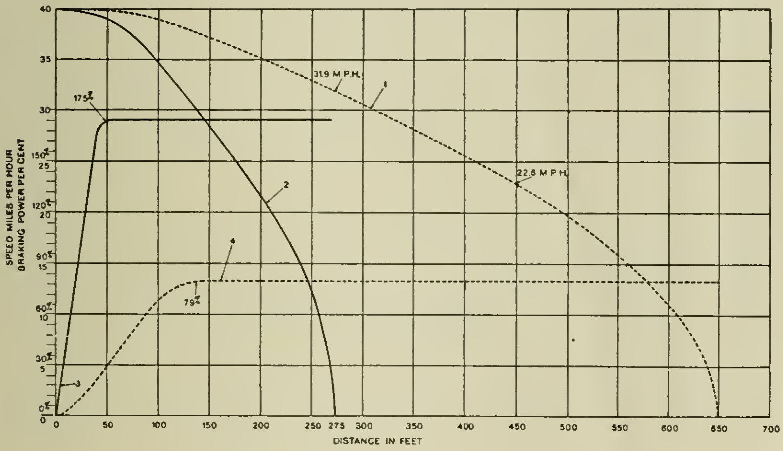
This shortening of the stopping distance with the electro-pneumatic train results from the increased percentage of braking power over that obtained with the old equipment train and also to the fact that *simultaneous* emergency action is obtained throughout the train, as against *serial* action with the old equipment.

It will be noted that the maximum braking power in the old equipment train was only 79 per cent., and was obtained at about *150 feet* from the point where the brakes were applied; while 120 per cent. braking power was obtained in the electro-pneumatic train after it had run about 40 *feet* from the point where the brakes were applied.

Fig. 3 represents comparative stops made with an emergency application of the brakes on an 8-car old equipment train and a 10-car train equipped with the most improved electro-pneumatic brake (main reservoir pressure used in emergency).

The maximum braking power obtained with the improved electro-pneumatic equipment is 175 per cent., as against 79 per cent. with the old equipment. The latter train ran 650 feet before coming to a stop, while the former train was brought to a standstill in *275 feet.* As the old equipment (P. M.) train passed the *point* where the improved electro-pneumatic equipment train stopped, it was running at a speed of 31.9 miles per hour (79¾ per cent. of the initial speed), with 63½ per cent. of its original energy; and at the *time* the improved electro-pneumatic train was brought to a stop, the old equipment train was still running at the rate of 22.8 miles per hour (57 per cent. of its initial speed), with 37½ per cent. of its original energy remaining.

Fig. 3.

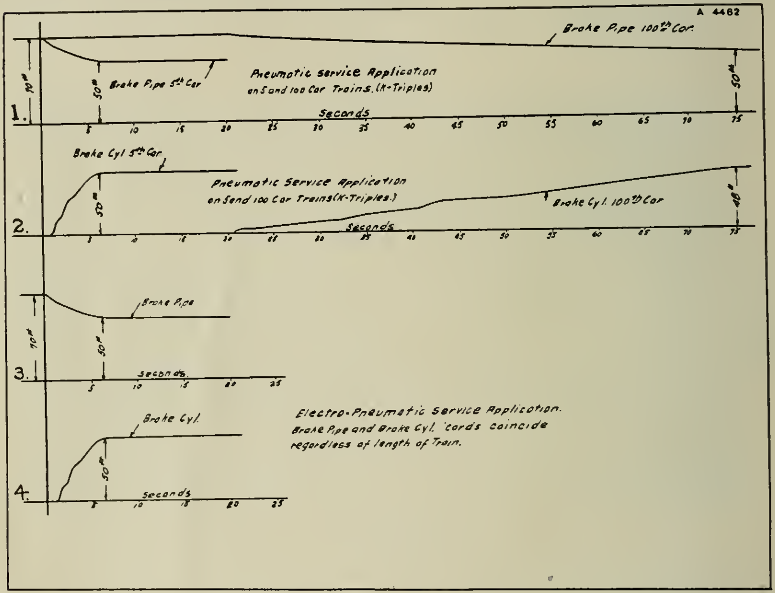


By comparing the curves for the electro-pneumatic equipment and the *improved* electro-pneumatic equipment, it will be seen that the braking power for the latter is greater than the former by 35 per cent. and its stopping distance is 75 feet shorter. This is due to the fact that main reservoir pressure (approximately 100 pounds) is obtained in emergency operations, thus giving the high braking power.

To further show the immense value and powerful effectiveness of the improved form of electro-pneumatic brake, the following might be added:

The 10-car train, weighing 331 tons and running at a speed of 40 miles per hour, has a kinetic or "wrecking" energy of 17,800 foot tons, equivalent to raising a *ton weight* to the height of *17,800 feet,* or to raising the *whole train* to a height of *54 feet.*

FIG. 4.



This energy is entirely dissipated by the brake and the train brought to a stop in 9¼ seconds, and in a distance of 275 feet from the point where the brakes were applied.

Fig. 4 shows four diagrams. Diagram No. 1 illustrates the great difference in the rate of brake pipe reduction between a 5-car and a 100-car train when making a pneumatic service application. Comparing the results obtained from the two trains, it will be seen that with the 5-car train the brake pipe reduction started immediately, and in 6 seconds time a 20-pound reduction was obtained; while with the 100-car train the reduction did not start until 20 seconds time, and it required 75 seconds to obtain a 20-pound reduction.

Diagram No. 2 shows the rise in brake cylinder pressure resulting from the brake pipe reduction shown in Diagram No. 1, and is proportional thereto.

Diagram No. 3 shows the drop in brake pipe pressure.

Diagram No. 4 shows the rise in brake cylinder pressure resulting from an electro-pneumatic service application. Since the electro-pneumatic operation is simultaneous, the same brake pipe and brake cylinder cards would be obtained on every car in the train, regardless of the length of the train.

The advantages of the electro-pneumatic equipment are clearly shown here, as the time element is entirely eliminated, resulting in each car starting to do its share of braking simultaneously.

This simultaneous action of the brake eliminates the disastrous results due to the slack between the cars running in and causing shocks.

Fig. 5 shows two diagrams. The upper diagram illustrates an electro-pneumatic service brake application, showing the start of rise in brake cylinder pressure in 1.9 seconds and the maximum cylinder pressure obtained in 5.5 seconds, and all brakes applying simultaneously.

Owing to the simultaneous action of the brakes throughout the train, the braking power can be developed in a short time without discomfort to the passengers.

The lower diagram shows the results obtained from a pneumatic service brake application on a 10-car train. The time for starting the rise in brake cylinder pressure is shown as 2.75 seconds, and the time for obtaining the maximum brake cylinder pressure was 11 seconds. The difference in time between the first and tenth cars, in start of rise in brake cylinder pressure, was one second.

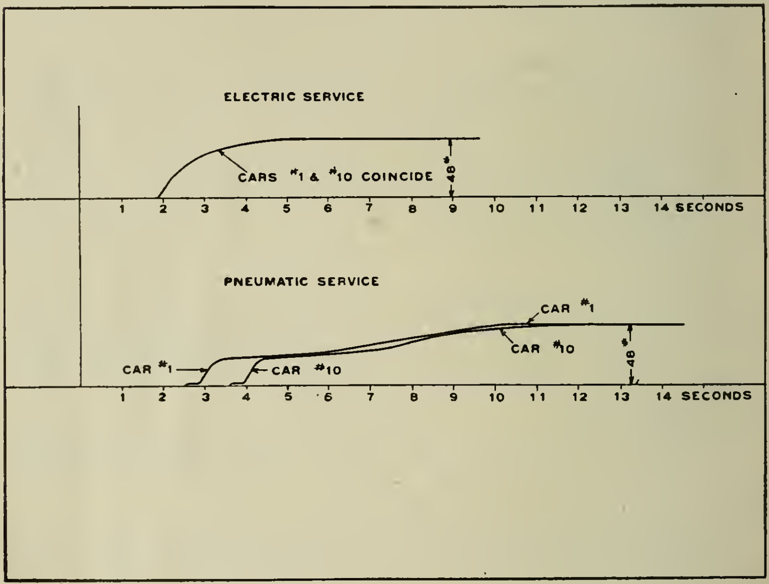
Fig. 6 shows two diagrams. The upper diagram illustrates the results obtained from an electro-pneumatic emergency application on a 10-car train.

The lower diagram shows the results obtained from a pneumatic emergency application on a 10-car train.

Comparing these diagrams, it will be seen that the only difference is in the time of transmission, and is all that should be claimed for the electric feature of the apparatus for emergency operation.

Fig. 7 shows two sets of curves. The upper curves illustrates the results obtained from a pneumatic emergency application with the "P.C." equipment. The maximum brake cylinder pressure was obtained in 2.8 seconds, resulting in a braking power of 180 per cent.

Fig. 5.

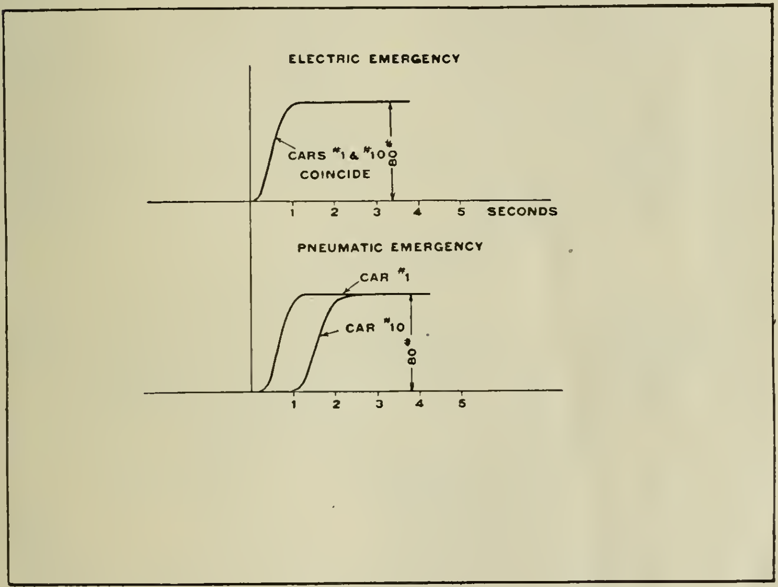


The lower curves show the results obtained from a pneumatic emergency application with a double "P.M." equipment (a complete brake equipment for each truck). The maximum brake cylinder pressure was obtained in 5.6 seconds, resulting in a braking power of 114 per cent.

These curves graphically illustrate the great difference that exists between different equipments, and that greater gain can be had by improving the pneumatic portion of the brake than by adding the electric features to the old equipment.

Comparing the work done by the two equipments, we will consider the stopping of two 10-car trains running at 60 miles per hour, the energy in these trains being 120.4 foot tons per ton weight. The train equipped with " P.C." equipment will stop in 575 feet shorter distance than the train equipped with the " P.M." equipment. If the train having the " P.M." equipment had the electric features added, without any other improvement, the stop would be shortened only about 70 feet; therefore, the stopping distance would still be 500 feet longer than with the train equipped with the latest improved automatic features (" P.C." equipment). This, because adding the electric features merely eliminates the time of transmission, the greater benefit being prevention of serious shocks and of break-in-twos.

FIG. 6.



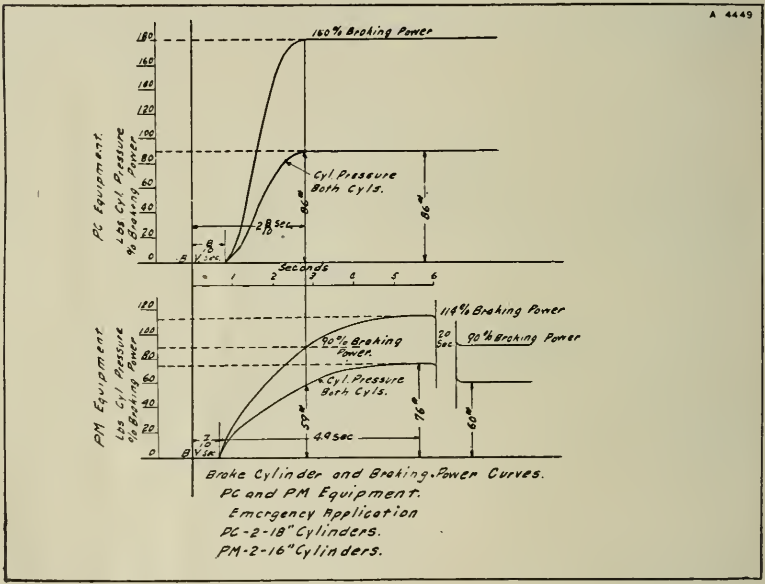
ELECTRO-PNEUMATIC BRAKES.

Difference in the conditions to be met, and certain advantages that might be employed with profit, have led to the development and commercializing of four chief types, or forms, of electro-pneumatic equipments, of which some distinctions can be mentioned.

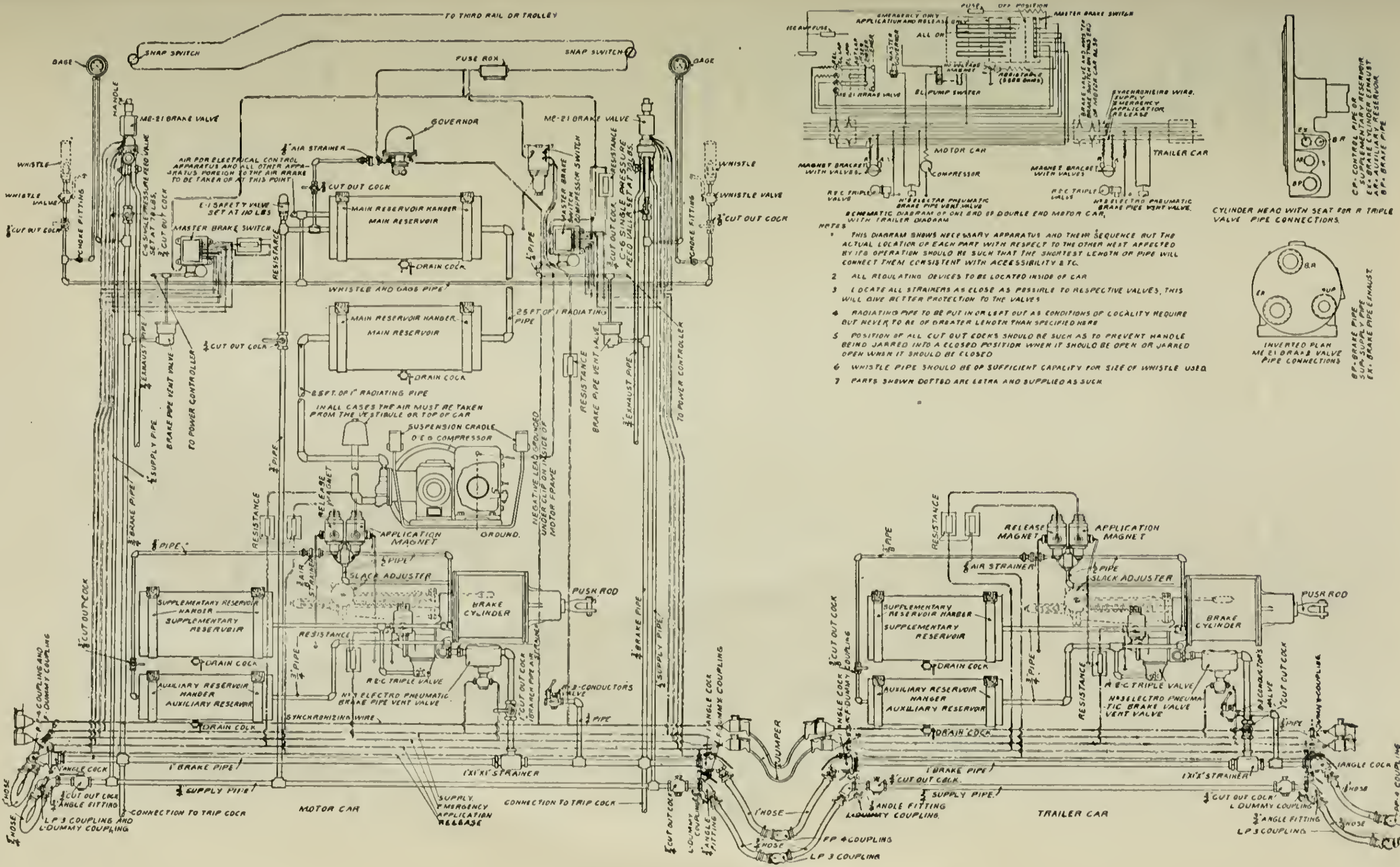
Traffic conditions, such as exist on the Interborough Rapid Transit Company's subways, very fittingly illustrate the necessity, as well as the advantages, of the electro-pneumatic system of brakes.

At the present time this road is carrying over one million passengers per day, and to handle this large number of people it is necessary to run trains of 10 cars at speeds as high as 40 miles per hour, and on a headway of 90 seconds.

FIG. 7.



In order to maintain the schedules with these heavy trains and to enable a train to stop, discharge passengers and start again without, in any way, delaying the following train, the highest permissible rates of acceleration and retardation are necessary. To obtain the former, new and improved motive power was installed with which it is possible to obtain a rate of acceleration of 1½ miles per hour per second (about three times that possible with the modern heavy passenger locomotive). To



SCHEMATIC DIAGRAM OF ONE END OF DOUBLE END MOTOR CAR, WITH TRAILER DIAGRAM

NOTES

1 THIS DIAGRAM SHOWS NECESSARY APPARATUS AND THEIR SEQUENCE BUT THE ACTUAL LOCATION OF EACH PART WITH RESPECT TO THE OTHER NEXT AFFECTED BY ITS OPERATION SHOULD BE SUCH THAT THE SHORTEST LENGTH OF PIPE WILL CONNECT THEM CONSISTENT WITH ACCESSIBILITY & TC.

2 ALL REGULATING DEVICES TO BE LOCATED INSIDE OF CAR

3 LOCATE ALL STRAINERS AS CLOSE AS POSSIBLE TO RESPECTIVE VALVES, THIS WILL GIVE BETTER PROTECTION TO THE VALVES

4 RADIATING PIPE TO BE PUT IN OR LEFT OUT AS CONDITIONS OF LOCALITY REQUIRE BUT NEVER TO BE OF GREATER LENGTH THAN SPECIFIED HERE

5 POSITION OF ALL CUT OUT COCKS SHOULD BE SUCH AS TO PREVENT HANDLE BEING JARRED INTO A CLOSED POSITION WHEN IT SHOULD BE OPEN OR JARRED OPEN WHEN IT SHOULD BE CLOSED

6 WHISTLE PIPE SHOULD BE OF SUFFICIENT CAPACITY FOR SIZE OF WHISTLE USED

7 PARTS SHOWN DOTTED ARE EXTRA AND SUPPLIED AS SUCH

CYLINDER HEAD WITH SEAT FOR A TRIPLE VALVE PIPE CONNECTIONS

CP - CONTROL PIPE OR SUPPLEMENTARY RESERVOIR
EX - BRAKE CYLINDER EXHAUST
AR - AUXILIARY RESERVOIR
BP - BRAKE PIPE

INVERTED PLAN ME 21 BRAKE VALVE PIPE CONNECTIONS

BP - BRAKE PIPE
SUP - SUPPLY PIPE
EX - BRAKE PIPE EXHAUST

obtain the latter, since the time element of the serial operation of the best and quickest automatic air brake made the 90-second headway impossible, it was necessary to install a new and improved system of brakes.

Not only is time an important factor, but smoothness of operation is essential on account of the number of passengers standing, who in the case of rough stops are often injured, which is not only bad for them, but costs the railways much money for damages, etc.

The impossibility of the automatic air brake to handle the situation led to the development of an electrically-controlled air brake, the electrical equipment being an addition to the improved automatic brake, the highest order of pneumatic brake still being available in the event of a failure of the electrical attachments.

The principle of operation of the automatic brake is the same as described by your orator in a former paper read before this Institute.

The electrical operation will be described in what follows:

Fig. 8 is a piping and wiring diagram of this equipment as applied to the Interborough Rapid Transit Company's subway cars. This plate plainly shows the relationship existing between the automatic and the electro-pneumatic brakes, and that the latter can be added to any automatic brake equipment already in service.

This equipment consists of the standard Westinghouse Company's "AMR" equipment, some of which apparatus has been modified, and the following new apparatus:

The motorman's brake valve, which is the operating valve of this equipment, has been slightly modified by the addition of a revolving drum (carrying contacts) and four stationary contact fingers; this drum closes the circuit across the several fingers in the various electrical positions and thus causes the several electrical brake operations as desired by the motorman.

The *triple valve,* held in reserve, and used only in case of accident to, or disability of, the electrical features, has had a magnet and magnet valve added to its cylinder cap so that (by closing the proper circuit, which can be done by throwing the brake valve to the emergency position) *instantaneous* quick action is obtained throughout the train instead of serial quick action as heretofore.

The check valve case of this valve was changed so that the rubber-seated valve (formerly the emergency valve) allows the supplementary reservoir air to equalize with the brake cylinder and auxiliary reservoir, thus giving a higher maximum emergency cylinder pressure in less time than formerly.

The electro-pneumatic brake pipe vent valve is a new device which automatically vents brake pipe air to the atmosphere (thus causing serial quick action throughout the train) whenever a given rate of brake pipe reduction is exceeded. The operation of this valve in emergency also closes the circuit to the emergency magnet line, so that an instantaneous quick action or emergency is obtained whenever current is "on."

Another new device is the *application and release magnet bracket.* This device, as the name implies, consists of two magnets and magnet valves by means of which air can be admitted to, or exhausted from, the brake cylinder at the will of the motorman by the manipulation of the brake valve.

The various parts will now be described in detail.

Fig. 9.—The *ME-21 brake* valve is the operating valve for this equipment, and is composed of two distinct parts—one electrical, the other pneumatic. These two portions are mounted on the same shaft and are operated by one and the same handle.

The pneumatic portion of this valve is the same as former types of valves, but the electrical features are new and are placed above the pneumatic portion, and consist of a revolving drum attached to the same shaft as the rotary valve. This drum has four contacts which connect with corresponding contact fingers when the valve is rotated through its various positions.

The upper finger is connected direct to the trolley, the second finger to the application magnet line, the third to the release magnet line, and the lower one to the emergency magnet line.

The release magnet valve is normally open, hence there is no current flowing through the brake valve when in the electrical release position, which is also the running position for the pneumatic brake, and any air that is in the brake cylinder can flow to the atmosphere and cause the release of the brake.

In the electrical lap position, the upper and third fingers are in contact with the drum, closing the release magnet line circuit, energizing the release magnet, closing the release magnet valve and separating the brake cylinder from the atmosphere; in the electrical service position, the first, second, and third fingers are in contact with the drum, and current is still flowing through the release magnet; the application magnet line circuit is also closed, thus opening the application valve, which, in turn, opens the relay valve and allows auxiliary reservoir air to charge the brake cylinder.

In all electrical positions of the brake valve the brake pipe charging port is open, thus maintaining the brake pipe and auxiliary reservoir air at initial pressure. In the pneumatic lap position all ports are blanked. In the first pneumatic service position there is a small port open from the brake pipe to the atmosphere, which gives a suitable rate of brake pipe reduction to cause a service application on a 5-car train.

In the pneumatic lap position and first service position the electrical connections remain the same as in electrical application position; these connections are maintained in these positions to insure getting a brake application in case the motorman should move his brake valve beyond the electric application position.

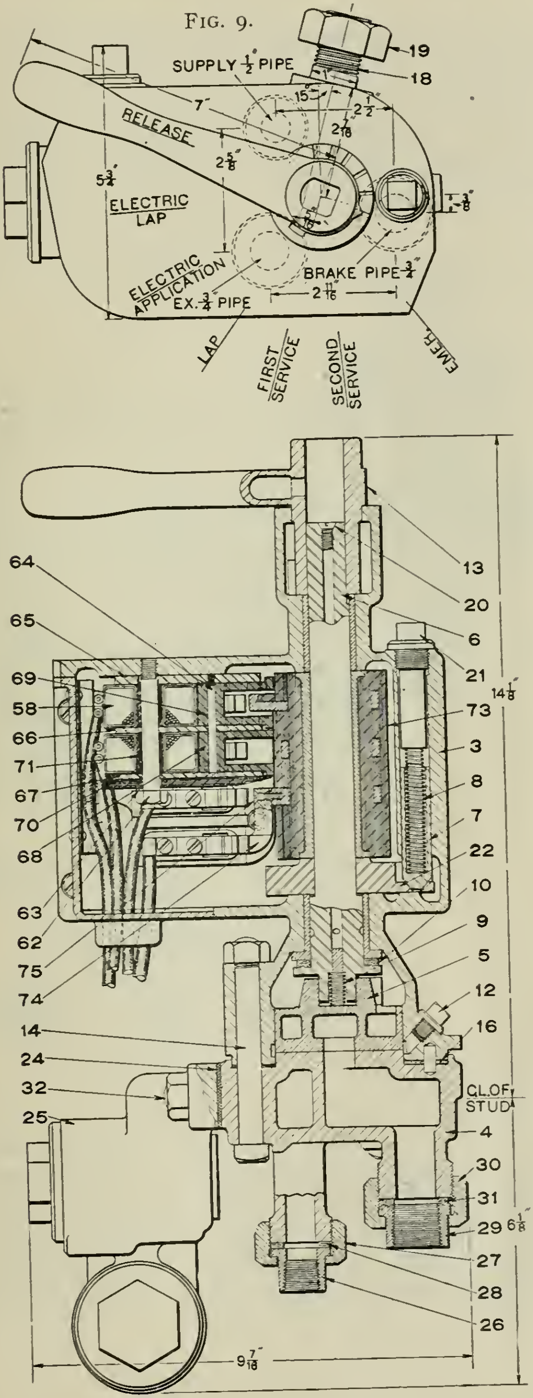
In the second pneumatic service position there are two ports open from the brake pipe to the atmosphere which give a suitable rate of brake pipe reduction to cause a service application on a 10-car train.

In the emergency position there is a large port opening from the brake pipe to the atmosphere which gives a rapid enough rate of brake pipe reduction to cause the brake pipe vent valves to operate in quick action. At the same time connection is made between the trolley and emergency line contacts so that, if the current is "on," the emergency line and magnet are energized and cause the emergency magnet valve to open, and this, in turn, forces the triple valve over to the emergency position; thus, with current "on," the electro-pneumatic emergency will prevail, otherwise purely pneumatic emergency will result.

Fig. 10 shows a diagrammatic cut of the *R-2-C triple valve*, which is used with this equipment. This is the standard R-2 triple valve slightly modified by embodying a new cylinder cap having a magnet and magnet valve, and a new check case.

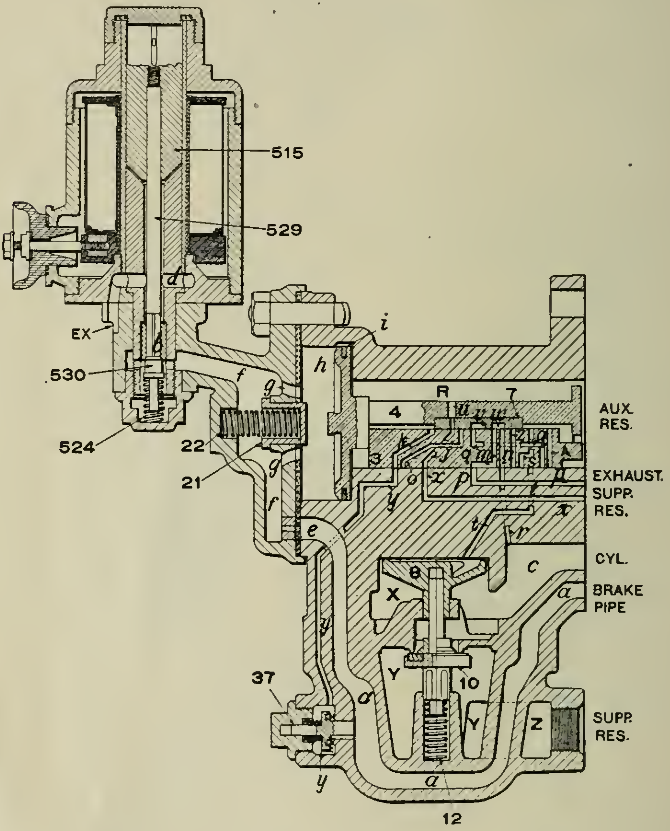
The magnet on the cylinder cap is connected to the emergency magnet line and is energized whenever this circuit is closed (which closing may be caused by the brake valve being moved to the emergency position, or by the brake pipe vent valve

FIG. 9.


SUPPLY ½″ PIPE
15°
7″
2½″
RELEASE
2 1/16″
2⅝″
5¾″
ELECTRIC LAP
⅜″
ELECTRIC APPLICATION
BRAKE PIPE ¾″
EX. ¾″ PIPE
2 11/16″
LAP
FIRST SERVICE
SECOND SERVICE
EMER.
14⅛″
C.L.OF STUD
6⅛″
9 7/16″
)

closing its switch, due to burst hose or pipe, or separated train, etc.). This, in turn, opens the emergency magnet valve and connects the triple valve piston cylinder to the atmosphere, and since this cylinder is charged through a 1/16-inch choke, its pressure drops to zero almost instantly and causes the triple valve to go into the emergency position.

Fig. 10.



The check valve case was modified by removing the ordinary brake pipe check valve and supplying a small rubber-seated valve for the quick recharge and quick service features of the triple valve. The emergency valve is still embodied in the valve, but its duties are somewhat changed, in that supplementary reservoir pressure is now under this valve instead of brake pipe as heretofore. Thus, when the triple valve moves to the emergency position, air from the auxiliary reservoir forces the emergency piston downward, unseats the emergency valve, and permits the supplementary reservoir air to equalize with the brake cylinder and auxiliary reservoir. By the use of this large valve the maximum brake cylinder pressure is of higher value and is obtained more quickly than was formerly the case.

This change in the check valve case makes this a plain automatic instead of a quick action automatic, triple valve as previously, and, consequently, since trains of more than five cars are to be handled, it will be necessary to have a brake pipe venting device in the equipment.

Fig. 11.

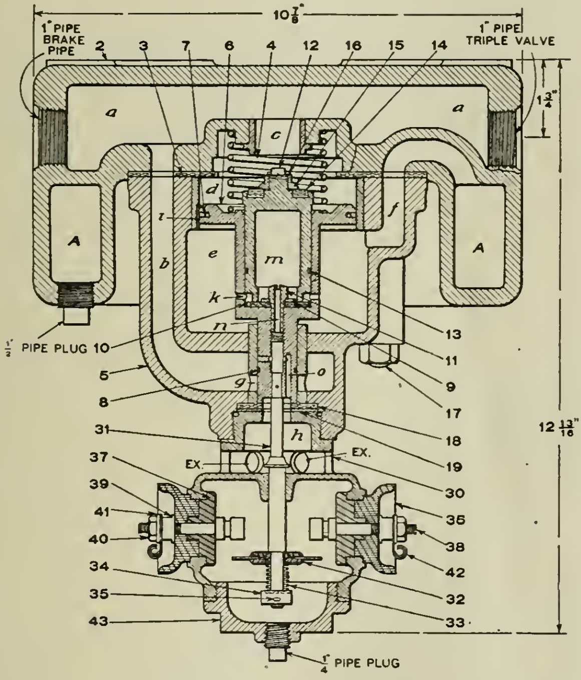


Fig. 11 shows the *electro-pneumatic brake pipe vent valve,* standard for this installation. This valve is placed in the branch pipe leading from the brake pipe to the triple valve, and is composed of a small reservoir and a body which encases a double or telescoping piston device. Brake pipe air enters the cored passage leading directly through the reservoir portion and flows through same to the brake pipe connection of the triple valve; this cored passage has a side outlet which leads down to the top of double piston, forcing both down against their seats, so that brake pipe air cannot escape around the lower end of the large piston's stem, and air from the chamber under the large piston cannot escape past the lower end of the small piston to the atmosphere. The chamber inside of the small piston is always open to the atmosphere by means of the small vent through the screw (which holds its seat in place) and the large piston stem.

Brake pipe air, which is always present above the double piston, is free to flow through the feed groove and charge the reservoir in the largest portion of the valve. This feed groove and reservoir are so proportioned to each other that during service brake pipe reductions the air in the reservoir can flow back through this feed groove into the brake pipe and thence to the atmosphere, and the pistons remain in their release or normal position. But if this service rate of brake pipe reduction be exceeded, the feed groove cannot accommodate the volume of this reservoir and, consequently, the pistons will be lifted out of their normal positions and moved to the emergency position. In this position the large piston rests against the reservoir gasket and the small piston is still down against its seat. With the pistons thus, the lower end of the large piston stem opens the ports in its bushing and also through its seat, thus allowing brake pipe air to escape through these ports to the atmosphere. The small piston is still seated downward, and remains there until the brake pipe air above it, which is reducing in pressure, and the reservoir air beneath it, which remains practically at initial pressure, have a differential of about 40 pounds, when it will be moved upward and brought to rest against its valve seat. This 40-pound differential is necessary, owing to the small area exposed to reservoir pressure, as against full area of the piston to the brake pipe pressure. When this piston lifts and seats upward, the row of ports around its lower end are opened, and the reservoir air can then drain to the atmosphere. When this reservoir pressure has dropped to a point slightly lower than that in the brake pipe, the large piston will be returned to its normal or release position, the smaller piston remaining seated upward until the brake pipe pressure is again restored.

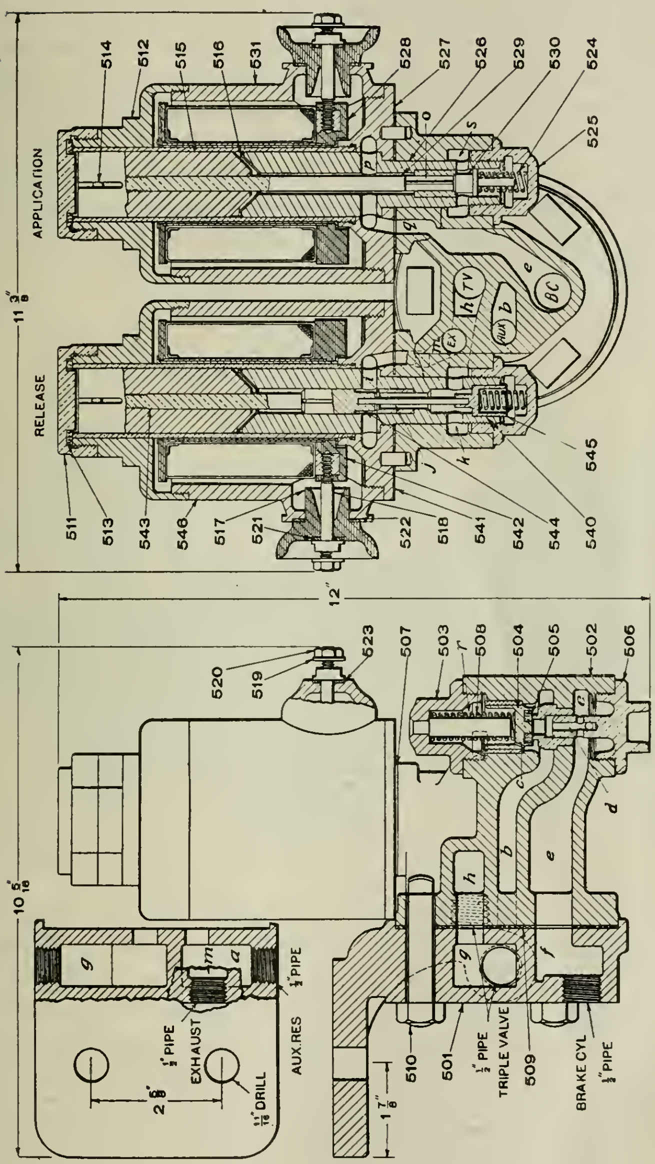

APPLICATION
RELEASE
11 3/8"
514
512
515
516
531
528
527
526
529
530
524
525
o
s
p
q
e
BC
h
TV
b
AUX
EX
i
j
k
545
511
513
543
546
517
521
522
518
541
542
544
540
12"
520
519
523
507
503
r
508
504
505
502
506
c
c
d
b
e
h
g
f
m
a
g
10 5/16"
1/4" PIPE
1/2" PIPE
EXHAUST
AUX.RES
2 5/8"
11/16" DRILL
1 7/8"
510
501
1/2" PIPE
TRIPLE VALVE
509
BRAKE CYL
1/2" PIPE

FIG. 12.

The raising of the pistons, due to the sudden reduction of brake pipe air, also raises the copper disk which is attached by a small rod to the large piston stem; this disk closes the circuit between the trolley and the emergency magnet lines by connecting the two contacts shown in the lower portion of the valve.

Thus, if current is "on," the instantaneous emergency will prevail, but if current is "off," the venting of brake pipe air at any vent valve causes the next nearest vent valve to operate, and thus the serial venting of brake pipe air, and, consequently, emergency action is propagated throughout the train.

Figs. 12 and 13 will be considered jointly.

Fig. 13.

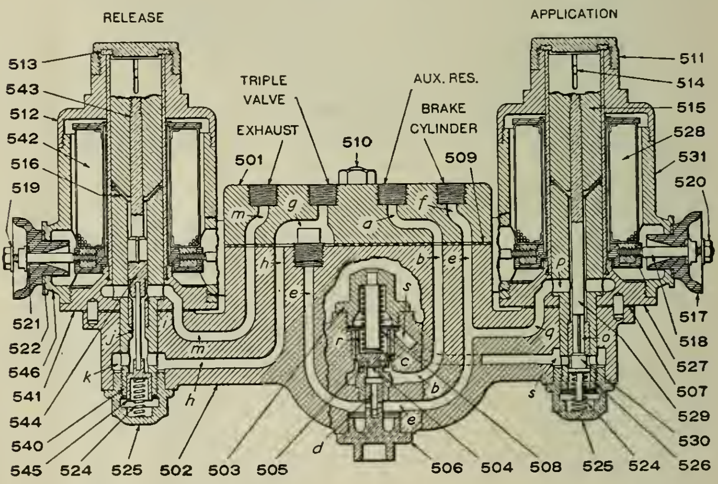


Fig. 12 is a vertical section taken through the *magnets* and valves of the *application and release magnet bracket.* From this view you will see that the two magnets are nearly identical and that, by means of their armatures and stems, they operate two valves. The release magnet armature stem and release valve are integral, and this valve is normally open, so that the brake cylinder is normally connected to the atmosphere. The application magnet armature stem operates a separate valve, which valve is normally closed.

Fig. 13 is another view of this bracket, showing a section through the relay valve and the special choke fitting or cap nut.

The magnet bracket has three pipe connections, viz., the supply from the auxiliary reservoir, the brake cylinder pipe, which connects the relay valve to the brake cylinder, and the release pipe, which connects the triple valve exhaust outlet to the magnet bracket. The exhaust opening is also tapped and may or may not be piped to carry the exhaust of the brake cylinder air away from the magnet bracket.

When an electro-pneumatic brake application is desired, the motorman moves his brake valve handle to the electric service position, but in doing so he must pass over the electric lap position, in which the release magnet is energized and its valve closed. Thus the cored passage leading from the brake cylinder to the atmosphere, *via* the triple valve exhaust port, is closed, and any air admitted to the brake cylinder will be retained there. With the brake valve in electric service position the release magnet is held energized, and the application magnet is also energized. This pulls the application magnet armature downward, and its stem forces the application valve from its seat and vents the top of the relay valve to the brake cylinder. Auxiliary reservoir pressure is always present under the outer area of this valve, and by means of a small drilled hole this air can equalize into the chamber above the relay valve, and thus, since the inner area of the under side of this valve is connected to the brake cylinder and thence *via* the release magnet to the atmosphere, the same is held seated. The relay valve chamber is connected to the under side of the application valve, and this chamber is normally bottled up.

When the application magnet is energized and the application valve opened the relay valve chamber is connected to the brake cylinder. This causes a drop in pressure which the small drilled equalizing port cannot supply, and consequently the relay valve is lifted by the auxiliary reservoir air, and the latter is allowed to flow down past this valve and through the special choke cap nut into the brake cylinder.

If the application magnet is energized for an instant and then de-energized, allowing the application valve to close, the pressures above and below the relay valve will very quickly equalize, closing this valve and permitting only a partial application of the brake. This operation may be repeated several times until the maximum brake cylinder pressure is obtained.

If the maximum pressure is desired quickly, the application magnet is held energized by allowing the brake valve to remain in electric service position. Under these conditions, the relay valve will remain open until the auxiliary reservoir and brake cylinder pressures have equalized, or, if desired, as is here the case, the relay valve may be loaded with a spring, thus making it an excess pressure valve, in which case the brake cylinder pressure will be less than the equalization of the auxiliary reservoir and brake cylinder pressures by an amount equal to the tension of the relay valve spring.

For example, if the tension of this spring represents 10 pounds per square inch on the valve area of the relay valve, then the highest electro-pneumatic service cylinder pressure will fall 10 pounds below the equalizing point of the auxiliary reservoir and brake cylinder pressures, and since the triple valve remains in release position and the brake pipe keeps the auxiliary reservoir pressure at 70 pounds, this brake cylinder will be 70—10, or 60 pounds.

Since the triple valve remains in release position during an electro-pneumatic application, the air admitted to the brake cylinder by the relay valve is free to flow back through the triple valve exhaust port and the magnet bracket release pipe to the under side of the release magnet valve. Then, when the electro-pneumatic release of the brakes is desired, the brake valve is returned to the electric release position, in which the release magnet circuit is broken and the release magnet de-energized. The brake cylinder air then lifts the release magnet valve and flows past the same to the atmosphere.

This release may be made straight away or may be graduated at the will of the motorman.

To graduate the electro-pneumatic release, the motorman moves his brake valve handle to the electric release position for an instant and then back to the electric lap position. By this manipulation the release magnet is de-energized and then is again energized. This permits the release magnet valve to stay open for a few seconds only, and, consequently, a partial or graduated release of the cylinder pressure takes place.

The admission of air to the brake cylinder is direct, so that the rate of rise of brake cylinder pressure may be made whatever is desired, and may also be controlled by the special choke cap nut in the magnet bracket, the area of which choke is made proportional to the brake cylinder volume with which the magnet bracket is to be used, so that the rate of increase of brake cylinder pressure will be uniform for all sizes of brake cylinders.

The release of the brake cylinder pressure is made through the triple valve exhaust, so that the time of release will be the same for either automatic or electro-pneumatic operation; this also eliminates the necessity of a double check valve or similar device which would otherwise be required to separate the two methods of operation.

The relay valve is used so that we may have an amply large opening between the auxiliary reservoir and the brake cylinder to give the cylinder pressure desired in the required time and still enable this opening to be controlled by a comparatively small magnet.

Fig. 14. The *master brake switch,* with its "no-voltage magnet," further safeguards the brake operation and the train movements.

This device consists of a rotating drum having eight contacts and eight corresponding stationary contact fingers, these contacts and fingers being used in the various positions of the switch. The drum aforementioned is mounted on a shaft which has provision for a suitable handle, so that this drum may be moved to any of its four positions.

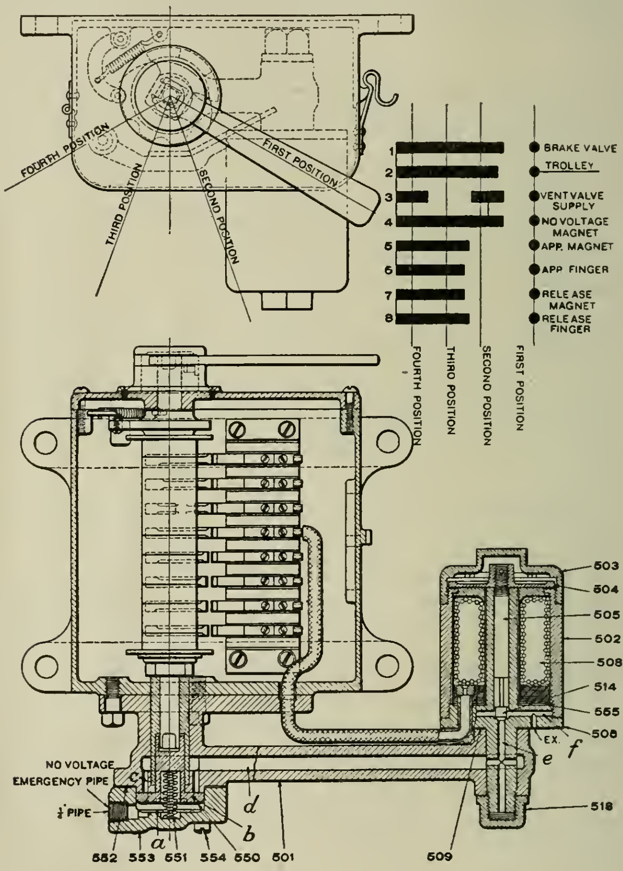
The arrangements of the stationary and drum contacts are shown on Fig. 14 (upper right-hand corner).

There are four positions for this switch. The first is the one in which no current is flowing to the brake valve or brake apparatus, and is the one in which the switch is placed on all, except the operating end of the controlling car in the train. Thus all the brake valves are "dead," except the one at the front end of the first car, and this must necessarily be so because the brake valves are carried in pneumatic lap position on all except this car, and when in pneumatic lap position the trolley, application, and release contacts are bearing against the contact drum. In the second position current is flowing to the brake valve, vent valve, and no-voltage magnet, but the application and release magnet lines are cut out. In the third position all connections are made except to the vent valve; and in the fourth position all electrical connections are closed, so that the entire electro-pneumatic system is available. This is the position for the switch on the controlling end of the train.

The handle of this switch is guarded so that it cannot be removed (as is the case when the motorman leaves his train), except in the first position, in which all electrical connections are broken.

On the lower end of the drum shaft is a small rotary valve

Fig. 14.



which controls air communication between the "emergency valve" and the no-voltage magnet. This communication is closed in first position, but is open in the other positions.

The "no-voltage magnet" is what the name implies; to its armature is attached a valve and stem, which normally closes the opening from the emergency valve through the emergency pipe and the small rotary valve of the master brake switch to the atmosphere. Whenever the voltage drops low enough to render the electro-pneumatic brakes ineffective, this magnet cannot hold its valve closed against the pressure under it, and thus allows the air from the emergency valve to be vented to the atmosphere and cause an automatic emergency application of the brakes. The switch can now be reset by moving its handle to the first position, and the brakes may then be released pneumatically.

This feature absolutely safeguards against serious accidents or delays which might result from a loss of voltage, and is of particular value where a train is drifting. Otherwise, under these conditions (drifting), the current might fail, and the motorman would be unaware of this failure until he tried to make a brake application, and even then his train would run some distance before he realized that the brakes were inoperative, and by this time even a pneumatic emergency might be unable to prevent collision.

The latest *"synchronizing of pump labor"* scheme, with which, after the system has once been fully charged, one master governor (whichever has the highest "cutting-in" point) will control all the compressors in the train as a unit, consequently the danger of any one compressor running continuously is eliminated.

The foregoing is a description of the electro-pneumatic system as applied to the subway division of the Interborough Rapid Transit Railway of New York City in 1910.

The operation of, and the returns from, the systems have more than met expectations. Also, the equipment has gone a long way to establish the electro-pneumatic brake on a permanent basis, since it has proven itself the safest, most profitable and economical type of brake equipment.

(*To be continued.*)

Resistance and Thermo-electricity of Tantalum. H. PÉCHEUX. (*Mon. Sci.*, ii, 842, 137.)—The resistance increases with the purity of the tantalum filament. The principal coefficient of temperature increases with the purity of the metal. The thermo-electric power increases with the purity of the tantalum. Annealing increases the thermo-electric power.

Petrol Air Gas as an Adjunct to Coal Gas. W. KEY. (*J. Gas Lighting,* cxviii, 425.)—In order to prevent the deterioration in the illuminating power of coal gas due to low temperatures (40° F. and below) at the condenser outlet, it has been proposed to use reversible condensers, the gas at 140° F. being passed alternately through the condensers from the opposite ends. It is proposed, as a cheaper alternative, to prevent excessive deposition of tar in the condensers by introducing from 10 to 20 per cent. of cold petrol air gas through the covers of each hydraulic main. Besides cleaning the condensers and pipes from tarry deposit, the addition of the air gas effects considerable saving in the quantity of lime required and in the expenditure on labor on the purifiers.

Injurious Properties of Magnesium Chloride in Finishing Cotton Goods. E. RISTENPART. (*Z. Angew. Chem.,* xxv, 289.)—An investigation into the tendering of cotton goods when finished with sizes containing magnesium chloride, owing to the liberation of free hydrochloric acid. The following conclusions are reached: (1) An aqueous solution of magnesium chloride does not decompose at temperatures below 106° C., even when heated in a current of air or steam or in the presence of cellulose and any ordinary ingredient of a size. (2) Even when magnesium chloride is heated to 246° C., the free hydrochloric acid formed is only equal to about 2 per cent. of the weight of the salt taken. (3) Tendering of cotton goods finished with a size containing magnesium chloride cannot take place at temperatures below 106° C. Such goods can be exposed to the action of saturated steam and be decatized with it. (4) At higher temperatures, especially if long continued, the goods are tendered. One hundred degrees Centigrade is the highest temperature at which such goods can be safely dried. (5) Within this limit, magnesium chloride can be used with perfect safety, but such goods must not be subsequently subjected to severe hot pressing or calendering, nor exposed to superheated steam.

Preservation of Wood. E. PINOY. (*Comptes Rendus,* cliv, 610.)—Wood may be preserved from the attacks of fungi, such as "dry-rot," by soaking in a solution containing 2 per cent. of potassium bichromate and 1 per cent. of sodium fluoride, and then drying and exposing to light. After this it may be coated with a solution containing 5 per cent. of gelatin, 2 per cent. of bichromate, and 0.5 per cent. of sodium fluoride, which forms a varnish, when dried and exposed to light, and imparts a mahogany brown color to the wood. If already attacked by fungi, the wood must be disinfected, before treatment, with a mixture of denatured absolute alcohol and xylol containing 1 per cent. of corrosive sublimate; it is then steeped in baths of bichromated gelatin, of increasing strength, dried and exposed to light.

THE USE OF GAS FOR HEAT AND POWER; THE TESTING OF GAS.[1]

BY

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The use of gas for heat and power has rapidly increased in recent years. This is partly due to a reduction in the price of gas and to improvement in the service rendered by gas companies, and partly to the improvement of gas appliances in the direction of greater convenience and efficiency and to the invention of new appliances for the accomplishment of many results in new ways. With more than 1,300 gas companies in the country, with a combined capital of $1,000,000,000 and annual sales of $200,000,000, it is one of the most important of the industries.

I. THE USE OF GAS FOR HEAT AND POWER.

Coal Gas.

The first recorded suggestion of the use of gas for fuel was in the patent taken out in England in 1805 by F. A. Winsor for a process of "extracting inflammable air" from coal. The product was to be applied to heating as well as to lighting; but in spite of his great enthusiasm, Winsor was not successful in bringing about the utilization of gas for fuel, and little was done along this line until about 1825, when the first gas cooker was invented. From that time until about 1880 development was very slow.

One important invention, however, was that of Delbruck, who placed one tube inside another, using one for the gas and the other for the passage of the air, mixing the two at the point of ignition.

What are usually called bunsen burners in connection with gas stoves are a modification of bunsen burners, invented by Thomas Fletcher of England. The true bunsen consists simply of the familiar open tube of the laboratory with the gas nozzle and air ports at the base. Fletcher was the first to use a cap to diffuse the flame and reduce its liability to flash back.

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[1] Address delivered at the Celebration of the Centenary of the Introduction of Gas as an Illuminant, under the auspices of The American Philosophical Society, The Franklin Institute, The American Chemical Society, and The American Gas Institute, in the hall of The Franklin Institute, Philadelphia, Friday, April 19, 1912.

The last thirty years have witnessed a wonderful development of every kind of heating appliance, and the most modern gas lighting units make use of the gas for heating solid materials to incandescence instead of deriving the light from the luminosity of the flame itself.

Acetylene Gas.

Although acetylene gas was discovered in 1836 it was not until 1892 that its commercial development was made possible by Willson, who discovered a method of producing calcium carbide in large quantities. The application of acetylene to heating and power has been very recent indeed, and the use of acetylene and oxygen in the blow pipe has produced almost the highest temperature known to chemistry—a temperature approximating that of the electric arc, probably above 6,000° Fahrenheit.

Through this means welding has been successfully accomplished and several other important industrial applications have been found. Large steel bridge girders can thus be cut apart with ease. There seems to be a great field open for the oxy-acetylene flame.

Natural Gas.

The first use of natural gas in this country was probably in Fredonia, New York, in 1821, and before long it was being used in rare instances for heating purposes. In 1859, Drake drilled the first oil well, and, as natural gas was found in abundance, its use was greatly increased. At first it was only used near the wells, but from time to time some enterprising individuals would run pipes from nearby wells to their homes and villages.

At first it was used in the coal or wood stoves for cooking and heating and at the wells for power by piping it directly to the cylinders of steam engines and using its expansive force as a substitute for steam.

The waste of gas for many years was very great, no interest being taken in making economical appliances, or even in turning the gas off when not wanted.

The first company formed exclusively for the distribution of natural gas was in 1872 in Titusville, Pennsylvania, since which time its use has become quite extended.

As a fuel, natural gas is burned in almost exactly the same way and with almost the same appliances as manufactured gas. It may be used in the ordinary gas range, hot plate, water heater, or other gas burning appliances, the only change necessary being that because of the higher pressure the gas orifices should be smaller, and because of the higher heating value less gas is necessary to produce the same results. Furthermore, the application of natural gas to coal burning installations of all kinds is very simple and, as a rule, very efficient.

The growth of the business in the last thirty years is shown by these figures from the United States Geological Survey, representing the approximate value of natural gas produced in the United States:

In 1882	$ 215,000
In 1892	14,870,714
In 1902	30,867,863
In 1909	63,206,941

Producer Gas.

Producer gas, the gas made from cheap fuels, using oxygen from the air to produce carbon monoxide, has come into prominence within the last twelve years. Although only a few scattered installations are reported as having been made in the United States prior to 1900, there are now probably two hundred or more plants together having an output of over 50,000 horse-power.

The two principal types of gas producers are the suction plant, used for small units below 300 horse-power capacity, and the pressure plant used for larger outputs. The suction plant receives its name from the fact that the engine develops its charge of gas in the producer by means of its own suction stroke. The pressure plant develops its gas under a slight pressure due to the introduction of an air and steam blast, and the gas is stored in a holder until it is required by the engine.

In Europe producer gas has been applied much more generally than in this country, but it is fast working its way into the industries here, such as glass furnaces, brick, pottery and terra-cotta kilns, lime and cement kilns, sugar-house char-kilns, silver chlorination and ore-roasting furnaces, etc. Although its use is accompanied by some dangers and disadvantages, the facts that it is the cheapest gas made per unit of heat and contains more of the energy originally in the coal than any other, and that it is possible to use very poor fuel in its production, make it a very economical gas when properly applied.

Conditions for Good Combustion.

One of the principal points to consider in the construction of heating appliances is the combustion of the gas. Efficiency, maintenance and many other important items are largely dependent on this feature. Some of the conditions for good combustion are:

(a) Complete and equal combustion of the gas must be had over every part of the burner and from every opening in the burner.

(b) Good mixing of air and gas, and equal proportion of primary air in all parts of the burner, are essential.

(c) There must be plenty of secondary air in the proximity of the burners, so that the flames will not be smothered, and good draft through the appliance to carry away the products of combustion.

(d) Flames should not impinge on cold surfaces in such a way as to cause incomplete combustion and so waste the heat and perhaps produce carbon monoxide.

(e) In those appliances where an adjustable air shutter is used, this shutter should be easily adjustable and yet should remain as adjusted. In those appliances that have a fixed air supply, the spuds should be readily accessible.

Each different form of appliance offers problems of its own. but the observance of these general conditions is important.

Development of Gas Cooking.

In the patent taken out by Mr. Winsor in 1805 for the manufacture of coal gas, we find the first recorded suggestion of the use of gas for cooking. But the actual utilization of gas for cooking was much later. Our earliest knowledge of a gas stove is to be obtained from a magazine of the year 1825 which described it as a piece of "gas apparatus for cooking by enclosing the circle of gas flames with its reflecting cone in a cylinder of tin, from the top of which a pipe takes off the burnt air." A drawing of the burner was also given and the writer adds: "A hot-plate has been heated by the gas, and it has also been employed to heat an oven. . . . It cannot be expected to succeed, however, except in the hands of persons whose scientific knowledge enables them to employ it with safety."

For a number of years there seems to have been little done in the way of actual trial, although the geniuses of the time were thinking about it and taking out patents. It is unlikely that we shall ever know who was the first user of gas for cooking; all we know definitely about the subject being that James Sharp, of Northampton, England, demonstrated the availability of gas cooking in his own house about 1830 or 1832, and a year or two later John Barlow, of Islington, London, had an apparatus for roasting, boiling and steaming in the kitchen of his house. This consisted of a tin oven, around the four sides of which, inside near the bottom, ran a gas pipe, fitted with small burners about an inch apart; on a stand alongside the oven were two or three rings of piping with burners, and over these were placed the boilers and saucepans.

After this, inventions for cooking by gas became more numerous, although the gas range at first gained very slowly in popularity.

In 1850 James Sharp, then of Southampton, delivered a lecture entitled "Gastronomy," in the course of which he roasted before the audience thirty-four pounds of beef, fifteen pounds of mutton, and twelve pounds of pork, and boiled and steamed twenty-four pounds of mutton and codfish, four fowls, eight plum-puddings, vegetables, etc., and baked pies and tarts, the whole being done with the expenditure of 156 feet of gas.

In the following year (1851) Alexander Graham, a well-known hotel proprietor of Glasgow, exhibited in the great Exposition in London a gas cooking oven, which was fitted with luminous jets inside. Mr. Graham made and sold a limited number of cookers for hotels and restaurants, but so far the use of gas ovens for domestic purposes was practically unknown.

A stove used in Philadelphia prior to 1860 is still in existence and forms part of the exhibition upstairs in connection with this Centenary. It has a peculiar boiling burner which consists of a piece of ⅛ inch pipe bent upwards into a sheet iron truncated cone, containing a perforated baffle plate of the same material. The upper end of the cone contained a fine wire screen covered with about ½ inch of fine gravel.

From this time on until about 1880, the history of the use of gas for cooking was an exceedingly slow development. In 1860, the *Cincinnati Gazette* said: "At present about 100 families are cooking with different kinds of gas stoves."

The development has taken a faster pace in recent years and thus has brought us to the present state of efficiency and convenience. The gas cooking range of to-day is distinguished by the following features: The flow of the hot products of combustion from the oven burners is so directed that the food is evenly cooked top and bottom in any part of the oven; air space insulation of the oven walls prevents the loss by radiation of an undue quantity of heat; adjustable air mixers on all burners permit of the complete elimination of soot; the boiling burners are so set that the placing of vessels over them does not smother the flames, or cause incomplete combustion; the boiling burners and their fixtures are easily removed by the cook for purposes of cleaning and are put in place again with equal ease, and all details are aimed to combine efficiency and convenience.

Tests of the relative heat efficiency of gas ranges have been made, but such tests have not been sufficiently standardized so that numerical statements can easily be made. Further tests are desirable, and if greater attention is given to the question of efficiency and economy, it is probable that considerable further improvement will be made by manufacturers.

Gas Water Heating.

About 1825 Robert Hicks took out a patent in England for "Heating water in baths by means of burning spirits of turpentine, or carbonetted hydrogen gas in chambers, in the bath, or in tubes pasing through or under them."

Up to about 1890 there were really no convenient and economical water heaters. Since then the instantaneous hot-water heater has been developed and this has greatly augmented the use of gas ranges, the one being a very important adjunct to the other.

Gas water heating is one of the most important of the domestic uses of gas, and it is very desirable that water heaters be tested systematically and the results of tests made public for the information of users.

Gas Room Heating.

About the year 1833 a patent was granted to one Richard Barnes for heating buildings by the combustion of gas or oil, applying the flame either externally to tubes or chambers through which currents of air were passing, or else placing the flame inside the tubes or chambers.

Peckston in his "Practical Treatise on the Manufacture of Gas," published in 1841, says: "Coal gas has of late years been applied to the heating of churches, chapels, shops, counting-houses, etc., . . . and has been found to answer the purpose intended." The stove described closely resembled the cooking stove of 1825, except that it was provided at the top with a register instead of the flue.

A form of stove now very popular in England under the name of the "Gas-fire" and consisting of lumps of incombustible material heated to a greater or less degree of incandescence by gas burners so as to resemble a coal fire, was patented by Edwards, in 1849. Seven years later, Nathan Defries was granted a patent for a similar device, the "argillaceous material" specified having fastened upon it fibres of asbestos, which, upon lighting the gas, became incandescent. This was followed three years later by a patent granted to Reece for a stove in which the asbestos back was the main feature.

In spite of the limited use of gas for fuel a company called "The Gas Fire Company" was incorporated in England in 1852. This seems to be the forerunner of the many ill-fated attempts to do a purely fuel business by artificial gas.

Room heating is now one of the common uses of illuminating gas.

The Use of Gas for Industrial Purposes.

In 1806 Mr. Josiah Pemberton exhibited various forms of gas lights in front of his factory at Birmingham. He was the first to construct a gas stove, using it for the soldering required in his button factory.

About 1840, a Scotch manufacturer by the name of Macintosh made several tons of "cemented" steel by submitting iron at a dull red heat to the action of lighting gas. The carbon for the steel was derived from the gas.

In 1857 a patent was granted for the heating of irons for laundry work by means of gas, and in 1859 a soldering apparatus for continuous soldering by means of gas was described in the *Technical Press*. This included the use of a blast worked by a foot bellows.

In an advertisement of Elsner, of Berlin, in July, 1859, it was pointed out that there was scarcely a brand of domestic work, of industry, or of business for which a gas cooking or heating apparatus could not be recommended. Thus it is evident that the use of gas for industrial purposes is not of recent origin, and that it has not been brought about through a falling off in the use of gas for lighting, due to the increased use of electricity.

At the Paris Exposition of 1867 there was exhibited singeing apparatus for use in wool works, dye works and bleaching works. Jewellers were also using gas. Plants for chemical and metallurgical purposes and laboratory ovens were also shown.

About thirty years ago what seems to us a curious method of using gas was considerably in favor. This was its use under boilers for generation of steam for engines up to about two horse-power. At the Royal Agricultural Societies Exhibition, held in 1879, several forms of such boilers were exhibited.

In 1879 the South Shields Gas Company, an English concern, gave an exhibition of over 300 appliances in which gas was to be used for other purposes than lighting.

To-day there are about one thousand practical applications of gas in the industries, and a conservative estimate places the proportion of gas sold for fuel at one-half the total sales.

Air under Pressure vs. Gas under Pressure in Industrial Appliances.

The subject of air and gas under pressure is one that is receiving considerable attention at the present time, although the field has not been as extensively explored as the others that have been described.

In England and on the Continent there are a number of companies now operating to furnish gas at high pressure for private establishments as well as for the public street lamps. The result is that in Europe there has been more done with the gas under pressure than in America, while, on the other hand, America has probably made more use of the air blast with low-pressure gas. "The disadvantage of the latter for furnace heating is that the efficiency depends upon the two pressures remaining constant. Experience shows that under working conditions it is too much to expect that these will remain constant, but the main defect in air-blast burners up to quite recently has been that they were badly designed,—their mixing arrangements being inadequate. Such gas burners as those recently designed which do away with secondary air and improve the mixing of the air and gas are a great advance on previous designs."

"High-pressure gas should have a great field before it in the industrial world. It can be applied to all heating processes with efficiencies reaching in some cases at least 90 per cent. Its chief charm is its cleanliness and its simplicity; and in by far the majority of cases it compares well in cost with solid fuel."

List of the Processes in which Industrial Appliances are Used.

Some of the processes in which gas has been used in the industries are as follows:

(1) Hardening, tempering, and annealing of steel, and the heating of automatic heating machines.
(2) Melting of base and precious metals.
(3) Forging and drop forging.
(4) Welding, brazing, soldering, and rivet heating.
(5) Developing power and generating steam.
(6) Boiling liquids and melting of solids.
(7) Tire heating, and the heating of mangles and steel rolls.
(8) Heating japanning and embroidery ovens.
(9) Air tempering.
(10) Singeing of cloth.
(11) Heating branding irons.
(12) Firing china.
(13) Melting barium chloride and cyanide of potassium for hardening steels.

(14) Embossing and stamping presses.

(15) Heating muffle-furnaces, and assay work, and reducing sweeps.

(16) Heating oil tempering furnaces.

(17) Pressing irons, stoves, and machines.

(18) Heating searing iron.

(19) Matrix drying in printing.

(20) Roasting coffee and nuts, and popping corn.

(21) Sterilizing and pasteurizing.

These are a few of the many processes that might be mentioned, but they are typical as showing the wide variety of applications of illuminating gas.

Development of the Gas Engine.

The gas engine really dates from the year 1791 when John Barber patented an engine driven by gas obtained by heating wood, coal, oil, or other substance in a retort. After the gases had been cooled they passed through a pump in which they were mixed with air, to an "exploder." At the orifice of this exploder the gas was lighted, and issued, in a continuous stream of flame, against the vanes of a paddle wheel. This was not only the first gas engine but the first gas turbine, a form of machine not in existence to-day.

In 1794 Robert Street designed a pump driven by the explosion of turpentine vapor below the motor piston. In 1801 Philippe Lebon took out a patent for an engine to give alternate explosions on each side of the piston. Samuel Brown, in 1823, designed a motor to operate by atmospheric pressure in which he used an explosive gas flame to expel the air from the chamber.

In 1823 L. W. Wright patented his double-acting vertical engine combined with a governor to regulate the speed. In 1838 William Barnet suggested the compression system of gas motor. This experimental period of gas engine research may be said to have lasted for seventy years: 1791–1860. In the latter year, Lenoir of Paris produced the first practical gas engine to work rapidly and silently, with electric ignition by jump-spark.

In the years that have followed, improvement after improvement has been made until the amount of coal gas necessary to develop ignition horse-power has been reduced from 100 cubic feet to 14 and even 12 cubic feet per hour. Only the principal steps in the development can be mentioned.

In 1861 Million proposed compression and the use of a compression or combustion chamber. In 1862 Beau de Rochas took out a descriptive patent of the compression four-stroke cycle now known as the Otto.

Otto and Langen exhibited their free-piston atmospheric engine at Paris in 1867 and in 1876 Dr. Otto brought out his famous engine with the Beau de Rochas cycle.

In 1878 and 1879 Mr. James Robson, and in 1882 Mr. Dugald Clerk, patented two-cycle engines, and in 1884 Atkinson brought out a "differential" type with the strokes of the cycle of different lengths.

In 1890, when the Otto patent expired, many firms who had been making gas engines upon other lines brought out new designs, all working on the Beau de Rochas cycle. This gave a great impetus to the sale of gas engines. With the close of the century came the utilization of producer gas for power purposes; the manufacture of large-sized units over 600 horse-power by John Cockerill Company in Belgium and by Crossley and the Premier engine in England; the design of the Westinghouse throttling governor; and the Sargeant engine with cut-off governing; the rise of the natural gas engine in large units; and the double-acting gas engine with compression in America.

The two great classes of gas engines to-day are (1) the four-cycle or "Otto" type and (2) the two-cycle or "Brayton" type. The former, called also the internal combustion type, with heating at constant *volume,* has only one working stroke in four, the four strokes being: charging, compressing, firing, exhausting.

The two-cycle type, with heating at constant *pressure,* usually has two cylinders, one a compressing pump and the other the working cylinder.

A third type of engine which should be mentioned is the cycle with heating at constant *temperature* or Carnot cycle. The nearest actual approach to this cycle using gas is the Diesel engine.

I am indebted to the Chairman of the Committee on Gas Appliances of the American Gas Institute for most of the material contained in the above sketch of the history of gas appliances.

2. THE TESTING OF GAS.

Among the industries conducted by public service companies, none has perhaps been for so long a time and in so great detail subject to legal requirements and restrictions as the gas business. The value of the service rendered by a gas company depends upon the quality, quantity, and condition of the gas delivered. Many elements besides the energy content of the gas go to determine good or poor service. These various elements are enumerated more or less completely in many of the gas ordinances now in force. These ordinances are sometimes, therefore, very technical and detailed in character; in other cases, however, containing very meagre specifications. The method of preparing such ordinances, as well as the ordinances themselves, are very various. In some cases, old ordinances, long since out of date, so far as their technical specifications are concerned, are still in use; in other cases such ordinances have been more or less extensively amended: in still other cases entirely new ordinances have been drawn to supersede the old; in many cases no regulatory ordinances of any kind have ever been adopted.

The process of adopting a new gas ordinance is often long and painful. No recognized single standard of quality, purity, and pressure has ever been set up. Indeed, the conditions are so different in different places that a single standard is impracticable. It was because the standard of performance demanded of gas companies in different cities and states is so different, and because so much difference of opinion existed among engineers and experts as to what could fairly be required of a gas company under a given set of conditions, that the Bureau of Standards took up about two years ago a careful study of the subject of state and municipal regulations of the quality, purity, and pressure of the illuminating gas supplied by gas companies.

A compilation of all the state laws and city ordinances in force in the country was first made, and their technical requirements tabulated. A detailed study was then undertaken of the various features of such laws, and an attempt made to formulate a law that should contain reasonable standards of quality, purity, and pressure of the gas, and a reasonable set of operating requirements. In this study, a large number of the best informed gas experts in the country were consulted, either personally or by letter, and many gas plants visited by a representative of the Bureau. In this work, the Bureau has been greatly assisted by the responsible officers and members of the technical staffs of gas companies, both large and small, and by members of public service commissions, gas inspectors and consulting engineers. The Bureau has endeavored to consider all sides of the various questions involved, and has, of course, received very conflicting opinions on some questions. It has been a source of great gratification to those conducting this investigation to see the fairness and broad-minded spirit shown generally by representatives of the gas companies in discussing questions which affected them so vitally; and I wish to express on behalf of the Bureau our sincere thanks to them and to all others who have assisted us so willingly and discussed with us so frankly the many important questions involved in the work.

The results of this investigation have been recently published in one of the technical circulars of the Bureau of Standards, and it is our hope that it may be of great value both to city and state officials and to the gas industry in the preparation and revision of rules and laws controlling the distribution and sale of illuminating gas. The position of the Bureau in this matter, as in so many other, is advisory. It has no legal authority to enforce its conclusions, and no disposition to suggest federal legislation or regulation. It acts as an unbiased co-ordinating agency, to formulate the consensus of opinion of those best qualified to express opinions, on technical questions of great practical importance. If the work be well done, it will carry great weight; otherwise, very little.

A second investigation is in progress, and will be embodied in a separate publication. It will have to do with the methods and instruments employed in testing gas for its heating value, its photometric value, and its chemical purity, as well as in testing meters and measuring gas pressures. This will be designed to assist gas inspectors and engineers in determining whether the gas meets the specifications under which it is sold. A large amount of experimental work is being done at the Bureau, in testing methods and instruments, and in some cases improving both methods and instruments. and the results of this work will be ready for publication, it is hoped, some time within a year. This circular will be much more comprehensive than the " Notification of the Gas Referees of the City of London." The latter is accepted as authoritative not only in London but also elsewhere, to some extent even in the United States. It is hoped that the publications of the Bureau of Standards on gas testing may come to be regarded as authoritative and may prove to be of real value to the gas industry. To this end the Bureau is carefully studying the various questions involved, and seeking advice and information from many sources.

Candle-power Measurements.

The cande-power of a gas refers to the candle-power of a luminous flame as the gas issues from a specified burner at the rate of 5 cubic feet per hour. This is measured by comparison with some kind of flame standard, candles being the most used but least reliable standard. The pentane lamp is probably the best flame standard in use, in spite of its serious limitations. Oil lamps may be used safely if only moderate precision is required, provided they are frequently calibrated and used with care. But inasmuch as mantle lamps are so largely employed in lighting, and a high candle-power gas is not necessary for them, less importance attaches to photometric tests for bare gas flames than formerly, and less stringent requirements may be made as to the candle-power of the gas so measured. It is thus possible to obtain a given heat value and a better lighting service when using mantles at an appreciably smaller cost of manufacture of the gas. But although the photometric testing of gas is less important than formerly, the photometric testing of gas mantles and of other lighting appliances is more important than heretofore. The gas company can do much good by encouraging the use of good appliances, and many of the larger companies have adopted very progressive methods in this respect. The public needs information as to the best use of light (both gas and electric) in homes, in stores and factories, in public buildings and on the streets, and the lighting companies can do much good in this direction.

Tests of Gas Appliances for Heating, Cooking, and Industrial Uses.

An immense variety of gas appliances are used for household and industrial purposes, and here again the gas company can do much good by encouraging the best and safest, and setting a high standard in the matter of connecting such appliances. The committees of the American Gas Institute and the National Commercial Gas Association on gas appliances have done excellent work in this direction, and no doubt will continue even more actively than in the past. The standardizing and testing of such appliances and materials used in connecting them, and the careful determination of their efficiency and performance, are quite as important and practicable as the measurement of the efficiency of gas burners or mantles.

Tests for Impurities.

It is very important to have the gas free from such impurities as sulphur compounds and ammonia, and tests and penalties are usually prescribed to insure reasonable freedom from such impurities. Gas companies find it to their advantage to comply with such requirements, the tests are easily made, and they offer comparatively little trouble in the administration of the law. It would be desirable and to the interest of the gas companies, if still greater freedom from these impurities could be economically attained.

Gas Pressures.

One of the most important features of good gas service is a nearly uniform pressure, neither too small nor too great, and yet the tendency is toward higher pressures. It is also one of the most difficult conditions to meet, as is likewise the case in the distribution of electricity for lighting purposes. In both cases, heavy mains, feeders, boosters, and storage tanks or batteries are or may be employed to aid in maintaining steady pressures. But whereas the gas company enjoys an immense advantage over the electric company in its gas holders, it suffers a disadvantage due to the clogging of service pipes, and sometimes to differences in altitude of different parts of a city. Heating as well as lighting appliances require adjustment to suit the pressure, and after such adjustment has been made serious variations of pressure are detrimental to efficiency, and may even be dangerous. Hence pressure limits are set in regulatory ordinances, and measuring the pressures at various parts of a city is one of the duties of a gas inspector.

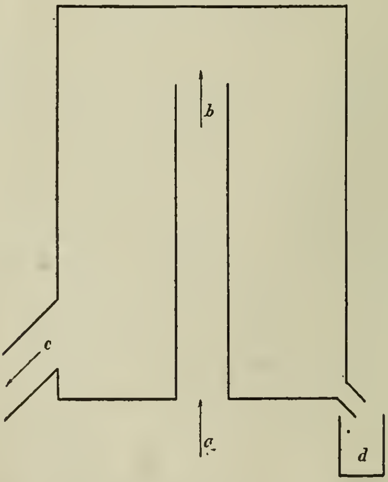
3. THE MEASUREMENT OF THE HEATING VALUE OF A GAS.

Gas is used for the production of heat, light, and power. For heat and power, and largely for lighting as well, its value is determined by the amount of energy it contains, and by its condition as respects pressure and purity. Its energy is measured by burning samples of the gas in a calorimeter. For this purpose, several different forms of instruments are available. The able Committee on Calorimetry of the American Gas Institute has done very valuable work in testing different forms of calorimeters, and in showing how they may be used in giving reliable results. The Bureau of Standards has also been making a thorough experimental study of gas calorimeters, the results of which will be published in the Bulletin of the Bureau. The results of this work will enable still higher accuracy to be attained in calorimetric work.

The Gross and Net Heat.

A gas calorimeter is an instrument for measuring the heat of combustion of a gas. In the usual type of instrument, the gas to be burned and the air to support combustion are admitted to the calorimeter at room temperature, while the products of combustion are cooled substantially to room temperature before

FIG. 1.



escaping, these products all being gaseous except that a certain amount of water vapor is condensed and collected as water at room temperature. The heat measured by the calorimeter under these conditions is called the *gross* heating value of the gas.

If the heat of condensation at room temperature of the water vapor condensed and collected is subtracted from the gross heating value, the remainder is called the *net* heating value. Usually the gross heating value is specified in city ordinances and in rules of the State Commissions (where a calorimetric test is required) and it is commonly believed (though erroneously) that it can be as accurately measured as the net value. As there is some confusion on this point, and as the measurement of the heat of combustion of gas is a very fundamental problem, I may be permitted to discuss the question rather fully. In the figure, representing diagrammatically a calorimeter, the air current entering and leaving the calorimeter is indicated by arrows, while the water vapor content of the air is indicated by letters.

$a =$ mass of water vapor *admitted* to the calorimeter (per unit quantity of gas burned) in the incoming current of air.

$b =$ mass of water vapor *formed* by the combustion of unit quantity of gas.

$c =$ mass of water vapor *escaping* (per unit of gas burned) with the products of combustion.

$d =$ mass of water vapor *condensed* in the calorimeter and collected outside.

Let $A =$ latent heat contained in a.
$B =$ latent heat contained in b.
$C =$ latent heat contained in c.
$D =$ heat of condensation at room temperature of d.

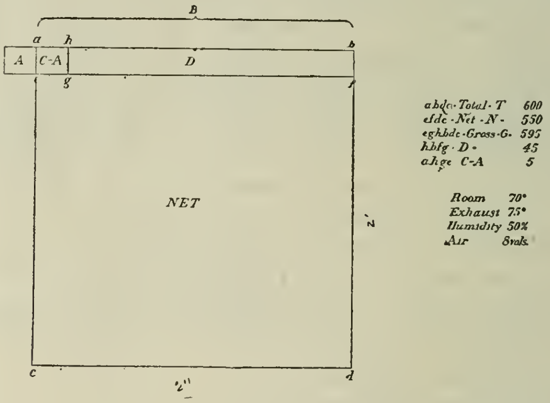
The Total Heat.

We will define the *total* heat T as the amount of heat measured by the calorimeter per unit quantity of gas burned if the air (admitted to the calorimeter at room temperature) is dry and if the water vapor formed by combustion is all condensed in the calorimeter, and both it and the products of combustion escape at room temperature. In other words, when gas is burned in dry air at room temperature, and the total products of combustion are cooled to room temperature, and all water vapor formed is condensed to water, the total heat given up in the process is called the *total heat*. Then, under these circumstances,

$$a = o$$
$$c = o$$
$$b = d$$

and the heat measured by the calorimeter is the total heat T. This would be the value found if the measurement were made with a bomb calorimeter. This is a larger quantity than the *gross heat* defined above, due to the fact that usually more uncondensed water vapor escapes from the calorimeter than enters with the incoming air. If the products of combustion carry away water vapor of mass c and latent heat C, the heat measured will be $T - C$. If the air entering contains water vapor of mass a and latent heat A, then the heat measured will be $T - C + A$. But this is defined to be the *gross heating* value, G. Hence

FIG. 2*a*.



$$G = T - C + A.$$

The net heating value N is the gross minus the heat of condensation D of the water deposited per unit of gas burned, d. Hence

$$N = G - D = T - C + A - D.$$
$$= T - (C + D - A).$$

But since $a + b = c + d$

and $A + B = C + D$

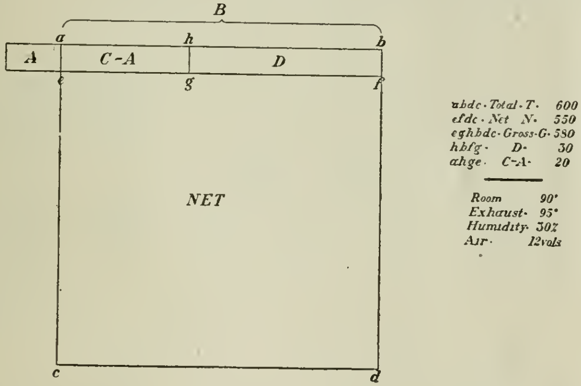
$C + D - A = B$

and therefore $N = T - B.$

$$N = T - B.$$

That is, the net heating value of a gas is the total heating value (as defined above) minus the latent heat of all the water vapor *produced by combustion*. Both the *total heat* and the *net heat* are independent of the amount of water vapor entering the calorimeter with the incoming air current or of the quantity of water vapor leaving with the products of combustion. That is to say,

FIG. 2*b*.

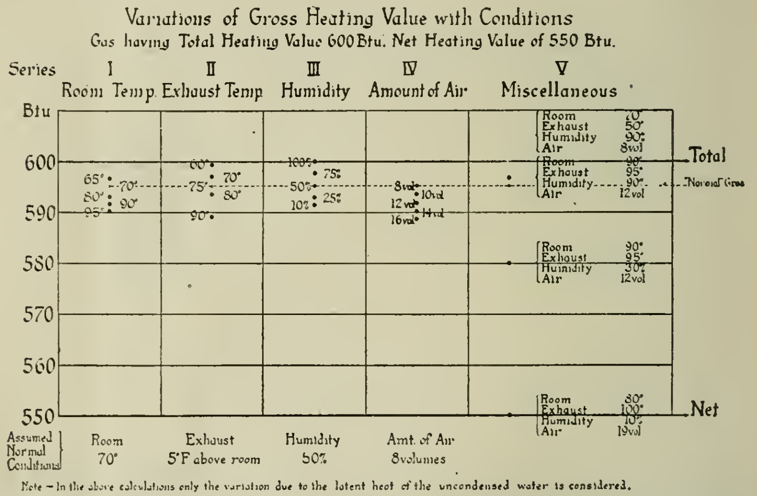


they are independent of the quantity and temperature of the air entering the calorimeter and of the atmospheric humidity, but depend only on the quality of the gas burned. The gross heat, on the contrary, varies with a, being a maximum when the atmosphere is saturated, and a minimum when it is dry. It also varies with c, being larger as c is smaller and vice versa. That is, the gross value varies with the atmospheric humidity and with the quantity and temperature of the gaseous products leaving the calorimeter. If the air enters dry and is great enough in quantity to carry away all the moisture produced by the flame, so that $d = o$, then the gross and net values are equal. If the air enters saturated, $a = c$ and $b = d$, and the total and gross values are equal.

Gross Heat Affected by Atmospheric Conditions.

Hence we see that the *total heat* and the *net heat* depend only on the gas itself, and are wholly independent of the condition of the atmosphere and of the quantity of air passing through the calorimeter (if there is enough air to insure perfect combustion). The *gross heat,* however, is a variable quantity, depending on both these factors as well as upon the gas itself. If, for example, a certain gas has a total heat of 600 B.t.u. and a net heat of 550 B.t.u. the gross heat as measured by a calorimeter may be anywhere from 550 to 600 (or may be outside these limits in extreme cases) according to the temperature and the atmospheric humidity at the time of the measurement and the quantity of air passing through the calorimeter.

FIG. 3.



Variations of Gross Heating Value with Conditions
Gas having Total Heating Value 600 Btu. Net Heating Value of 550 Btu.

Note — In the above calculations only the variation due to the latent heat of the uncondensed water is considered.

It will be seen from the above that the net heating value is a truer measure of the quality of the gas than the gross. It is the gross value, however, which is used generally as a test of the quality of the gas. Hence, even if the calorimetric work be correct to within one per cent. (and the net heat determined within one per cent.) the result may be in error by several per cent. if the gross value is used. Since the object of the work is to test the quality of the gas, the result should, of course, be independent of the state of the weather.

The effect of atmospheric moisture upon the light of a gas flame is even greater than its effect upon the results of a calorimetric measurement, but this effect is substantially eliminated in photometric testing if a flame standard is employed. The candle-power of a flame is greater in a drier atmosphere, being about 10 per cent. greater for a pentane of Hefner lamp in a dry winter atmosphere than in a moist summer atmosphere. The gas flame changes also, probably about the same amount, so that a photometric measurement of a gas flame against a flame standard does not give the real candle-power of the gas at the time, but does give a measure of what that candle-power would be if the flame were burning in an atmosphere of average humidity. This is as it should be, for the object of the photometric measurement is to test the quality of the gas delivered, for which the company is responsible. The gas company should obviously not be held responsible for changes in candle-power due to the atmospheric moisture. Thus, while the actual candle-power and the gross heating value both vary considerably with atmospheric humidity, the *relative* candle-power and the *net* heating value are both independent of atmospheric conditions, and hence may properly be employed in determining the light-giving and the heat-giving power, respectively, of the gas.

Specification of Unit Quantity of Gas.

In the foregoing discussion, the heating value of a gas has been expressed as the heat produced per *unit quantity of gas burned.* This unit as commonly employed is the cubic foot of gas at a normal barometric pressure of 30 inches of mercury, at a temperature of 60° F., and saturated with water vapor at this temperature. That is to say, if the gas is measured by a correct wet meter (containing water only) at 60° F., and normal barometric pressure, there will be no correction to apply to the meter reading. Under these circumstances, the gas will contain nearly 2 per cent. of water vapor, which is taken as normal. If, however, the temperature is higher and the barometer is lower, a cubic foot of gas will have a less energy content, that is to say, a smaller heat value, for three reasons, viz.: (1) because of the higher temperature, (2) because of the lower pressure, both of which decrease the density; and (3) bcause of the greater vapor pressure of water at the higher temperature, a greater percentage of the volume being occupied by water vapor. Hence, the heat produced in the calorimeter per cubic foot registered by the meter will be less; at 29 inches pressure and 90° F., it will be 11.5 per cent. less. This correction can easily be taken from tables prepared for the purpose, in which usually the first and third corrections are combined in one. (One is apt to infer from the descriptions often given that the correction for varying vapor pressure is not made, because it is not mentioned explicitly. Indeed, some tables do not take account of this.)

Effect of Barometric Pressure and Temperature.

These corrections enable one to determine from the calorimeter measurement the true net heating value of a cubic foot of the gas under normal conditions of temperature and pressure, and this is a measure of the quality of the gas. But the company delivers to its customers gas measured at actual existing barometric pressures, and no correction is made to the meter readings for variations in barometric pressures. The fluctuations above and below the mean barometric pressure in any given place may be ignored, inasmuch as they will balance out in the long run. But if the mean barometric pressure is below 30 inches the customer gets a less quantity of gas on that account, for the density and heating value are less in the same proportion as the barometric pressure is less than 30 inches. For example, Minneapolis is about 800 feet above sea level and has a mean barometric pressure of 29.2 inches more than 2 per cent. less than normal. Denver is 5,300 feet above sea level and has a mean barometric pressure of 24.7 inches, 17.7 per cent. less than 30 inches. Hence gas that shows 600 B.t.u. as tested in Minneapolis (*i.e.,* reduced to 30 inches) would give only 584 B.t.u. if reduced to the mean pressure at which the customer gets it. In Denver, gas that shows 600 B.t.u. by calorimetric test (*i.e.,* reduced to 30 inches) gives only 494 B.t.u. at the pressure at which it is delivered to the company's customers. In Boston, New York, Philadelphia, and all cities at or near sea level, the mean barometric pressure is practically 30 inches and the present practice is perfectly correct. This suggests the obvious fact that either the heat value should be calculated for the mean barometric pressure at which the gas is delivered to the users at any given place, or the meter readings should be corrected to normal barometric pressure. The latter would, of course, be very laborious in practice unless the meters were set so as to do this automatically.

The same remark applies, of course, to the temperature. Tests are reduced to 60° F., and if this is the mean temperature of the meter, no temperature correction is necessary to the meter readings. The mean annual *outdoor* temperatures of Boston, New York, Chicago, Denver, and Seattle differ by only a few degrees (averaging about 50° F.), so that there is probably very little difference in the average meter temperatures in the cities of the northern portions of the United States. New Orleans has an average temperature 20° higher, and hence there may be several per cent. less average heat value of the gas per cubic foot as delivered and metered to the customers in New Orleans, due to this cause alone. Buffalo and Minneapolis have somewhat lower mean temperatures than the average, and this tends to offset the effect of their lower barometer.

Two Aspects of a Calorimeter Test.

We see, therefore, that a calorimetric test of gas may be regarded from two different points of view. According to the first, the test gives the heat value of the gas per cubic foot *measured under standard conditions of temperature, pressure, and water vapor content.* The total or net value of this heat depends only on the composition of the gas, and could be calculated if we knew its chemical composition. The gross value as usually measured and defined depends to some extent on the atmospheric conditions and other circumstances of the test, and it is not as true a measure of the quality of the gas as the net heat.

According to the second point of view, the calorimetric test should give the heat value of a cubic foot of the gas as nearly as possible *as delivered to the customer,* and hence the correction for temperature and pressure should be, not to 60° F. and 30 inches barometric pressure, but to mean annual meter temperature and pressure of the city where the gas is sold. Then if a uniform heat value were required, the gas would be made of enough higher heating quality in a city of higher altitude or higher mean temperature than the average to offset the effect of smaller density. This would seem perfectly feasible except possibly for cities at high altitudes, where the difference is large, and here it may be better to make the correction either in the rate of the meter or the heat value required.

It may be urged that such corrections tend to complicate the sale and distribution of gas, and that the present methods are good enough in these particulars to be let alone. But I think this is not a correct view. What is the logic of trying to keep meters free from accidental errors greater than 2 per cent. and of trying to make calorimeter determinations correct to 1 or 2 per cent. if constant errors of 2 to 5 or even 10 to 15 per cent., or more, due to low barometer or to a higher or lower mean temperature than the average, are ignored?

To use an expensive calorimetric outfit in order to make the calorimetric determination accurate to a high degree is commendable. But to correct the result to 30 inches barometric pressure when the gas is burned in the calorimetric (and delivered to the customers) at an average pressure of say 29.2 inches as in Chicago or Minneapolis, or 24.7 inches as in Denver, is not in harmony with the accuracy of the experimental work.

I would not, of course, suggest that in all routine calorimetric measurements an attempt be made always to apply all possible corrections; but there should be a well formulated official specification such that a given mass of gas of a given quality tested by different persons would be found to give the same heat value (within reasonable limits to cover the errors of measurement); and, also, a given mass of gas tested by the same person and the same instrument, but under varying conditions of temperature, pressure, and atmospheric humidity, should give the same heat value.

Distinction between Volume and Quantity or Mass.

The cost of manufacturing gas is determined not by the volume the gas occupies after it is made, but by the *mass* of the gas and its quality; and, similarly, the value of the gas to the user is determined by the *mass* of the gas and its quality. A calorimetric determination under present methods tests the quality, the meter measures its volume, and no account is made of variations in density. As already stated, the fluctuations of atmospheric pressure above and below the mean may be ignored;

but the departure of the mean from the normal may be considerable, sometimes amounting to several per cent., and representing large sums of money in a large city.

A parallel case exists in the testing of coal for the purpose of calculating its value on a heat unit basis. The value of a cargo of a given kind of coal depends on two things: its total weight, and the average number of heat units yielded per pound of coal. In taking a sample for calorimetric test care is always exercised to get a representative sample, which is then sealed to prevent any change in moisture content, or other change. If the sample is dried before burning, the percentage of moisture is recorded, and the heat of combustion measured is reduced by the percentage of moisture so as to give the average heat value per pound of the coal as weighed on delivery. To dry the sample and burn it in a calorimeter, and report the heat value per pound of dry coal, and say nothing about the moisture content, would obviously be misleading. But if the moist coal is burned in the calorimeter, the heat per pound of the coal as weighed is directly determined and no separate determination or record of the moisture in the coal need be made.

To return now to the case of gas testing, it is seen that to measure the heat value of the gas per cubic foot under the condition in which it passes through the consumers' meters is what is really wanted. Of course, it is impossible to test the gas at each meter, hence the most that is practicable is to reduce the result not to 60° F. and 30 inches barometric pressure, but to the mean meter temperature and mean barometric pressure of the city where the gas is distributed. Such mean temperature and mean pressure are not difficult to determine at least approximately, and it would appear not impracticable to carry out such a method. In order to illustrate, in a concrete way, how the gross heating value as usually defined and measured varies under different conditions, the *total* and *net* heat being always the same for the same gas, I shall give a number of numerical examples. In each case suppose the same mass of gas is taken, the composition being such that 600 heat units for the total heat are given off, and 550 net, when one cubic foot of gas at 30 inches barometric pressure and 60° F. (saturated at that temperature) is burned.

In Fig. 2 the rectangle $a\ b\ c\ d$ represents the total heat, 600 B.t.u. The rectangle $a\ b\ e\ f$ represents the heat of condensation, B, of the whole amount of water vapor formed in the flame, and $h\ g\ b\ f$ is the part, D, represented by the water vapor condensed and collected. Hence $e\ f\ c\ d$ is the *net* heat, N, and $c\ e\ g\ h\ b\ d$ is the gross heat $N + D$. When the room temperature is 90° F., exhaust 95°, humidity 30 per cent., and air passing is 12 volumes, the gross heat is 580 B.t.u. If room temperature is 70°, exhaust 75°, humidity 50 per cent., and 8 air volumes are used, the gross is 595 B.t.u.

Fig. 3 shows the values of the gross heat at various temperatures, humidities, etc. In extreme cases, possible to realize but not likely in ordinary practice, the gross may be higher than the total or nearly as low as the net. A variation of 10 or 15 B.t.u. is, however, liable to occur even in the most careful work, due to varying atmospheric conditions.

The "Normal" Gross vs. the Net.

The above examples show that gas of a total heating value of 600 B.t.u. and of a net heating value of 550 B.t.u. *may* have a gross value anywhere between 550 and 600 according to the condition of the atmosphere and the rate at which air passes through the calorimeter, although under usual conditions the variation is relatively small. It is true, of course, that a wide range of gross value would probably never occur in any one place. Nevertheless, the specifications for taking the heat value of a gas should be so definite that the same result (within the inevitable errors of observation) would be obtained on a damp or dry day, in summer or winter. This will be true if the net value be specified, or if the gross value be specified under certain normal atmospheric conditions and a normal rate of flow of air. This would necessitate applying corrections for variations in the atmospheric humidity and for variation in the rate of flow of air, which latter is difficult to measure. Without such specifications the variations due to the atmosphere may be much more than the usual errors of the instrument except under uniform external conditions. In much of the best calorimetric work published, where very close agreement in different determinations has been found, the atmospheric conditions have been very uniform. If work done at different times shows different heat values, the difference is attributed to the difference in the gas. At the Bureau of Standards atmospheric differences have been made intentionally and the differences in the gross heat appeared at once.

It is very difficult indeed to measure the quantity of air flowing through a calorimeter, and if one varies the position of the calorimeter damper the rate of flow of air varies considerably. It may be possible to determine approximately by careful investigation the quantity of air passing through a calorimeter for a given rate of burning of a given gas, and so fix a basis for correcting the gross heat to a normal gross. Instead of attempting to specify the rate of flow of the air it is more usual to operate the calorimeter so as to obtain the highest gross value possible. But the maximum value will vary under different atmospheric conditions. Sprinkling the floor of the calorimeter room to raise the humidity and decrease the temperature of the atmosphere will increase the gross heat; raising the temperature of the room without such sprinkling will lower it. But neither operation would have any effect on the net value.

If instead of correcting the variable gross value to a constant "normal" gross we specify the total heat as defined above, we must correct the measured gross by adding C — A. That is, we must add the difference in the latent heat of the water vapor leaving the calorimeter and that entering it. This also requires a knowledge of the atmospheric humidity and the quantity of air passing through the calorimeter, and hence is not an easy correction to apply.

If, however, we specify the *net heat* of the gas, we require no knowledge of the atmospheric humidity or the quantity of air entering the calorimeter. We must, of course, have enough air to insure complete combustion, but an excess does little harm. For while an excess decreases the gross value measured, it also decreases by the same amount the correction D subtracted from it, thus leaving a constant difference, the net heat, *the only quantity that can be readily measured unaffected by atmospheric conditions.*

(No argument is here made for the net heat because some of the gross heat of the gas is not utilized in ordinary gas appliances.)

Shall the Actual Net Heat be Substituted for the Gross?

If it is granted in view of the above consideration that the net heat is the proper quantity to specify as indicating the quality of the gas, the practical difficulty remains that in many ordinances and rules a gross value of 600 B.t.u. is now specified, and it is difficult to change established practice. Even if a change could be readily made, 600 B.t.u. sounds better than 550 and some feel that the latter figure does not give the gas manufacturers credit for all the heat they have put into the gas. This difficulty, and the practical difficulty of changing established rules, can be largely overcome by allowing the gross value of 600, or the corresponding total, to remain in the rules and ordinances, but to add by way of amendment that *for purposes of test* 550 B.t.u. net (or whatever is found to be equivalent) shall be construed as equivalent to 600 gross. This would give at once a fixed standard, more satisfactory than the present gross or even a normal gross, and would at once remove one of the most serious objections to the present practice of gas calorimetry. To correct the measured net heat to the mean annual meter temperature and mean annual barometric pressure of the city where the gas is distributed, instead of to 60° F. and 30 inches barometric pressure (or to omit the correction for barometric pressure altogether), would be the next logical step in putting the calorimetric testing of gas on a more scientific and likewise a more businesslike basis. These two changes are, however, too important and too far reaching to expect that they could be agreed to and put into practice immediately. I suggest that a committee of the American Gas Institute working in co-operation with the Bureau of Standards might give the matter careful study, and report their findings to the Institute and the public. I believe that the Institute and the gas interests at large would favor the adoption of such changes in practice if on careful study they appeared to be just and practicable. To do so would be in harmony with the present tendency to adopt uniform standards of gas quality, so that 1,000 cubic feet of gas would mean the same thing, in actual service as nearly as possible in different places. No criticism is intended that such changes have not been adopted before. But now that instruments are more accurate and methods more perfect and requirements more exacting than ever before, we should be as careful in taking account of the varying density of the gas as we are in measuring its volume and quality.

The Bureau of Standards has not suggested these changes in current practice in its recent publication, but in the next publication on testing methods these questions will arise, and in studying them we shall hope for as cordial coöperation from the gas interests as they have given us in the first investigation.

The Automatic Sprinkler. ANON. (*Amer. Mach.*, xxxvi, 16, 642.)—*Insurance Engineering* considers that the automatic sprinkler is the greatest single factor of conservation in the industrial world to-day. There are certain classes of factories that could not endure without the protection afforded by this device, and it should be made compulsory by law to install this protection in all buildings of combustible or otherwise unsafe construction and arrangement where people congregate, whether by compulsion or of their own volition.

Lubricating with Turpentine. F. J. BADGE. (*Amer. Mach.*, xxxvi, 13, 497.)—Mr. Badge finds that lubrication with turpentine for drilling hard steel, such as spring-tempered steel, raised the production at least 40 times above that when no lubricant was used. An editorial note adds that a mixture half turpentine and half spirits of camphor is a good cutting compound. Nitric acid is used as a lubricant for turning tempered steel, but care should be taken that nitric acid does not get into the eyes.

Formation of Hydrogen Peroxide under the Electric Discharge. A. BESSON. (*Comptes Rendus*, cliii, 877.)—The discharge chamber was cooled to several degrees below zero and the pressure varied from 30 to 760 mm. The test used for hydrogen peroxide was the blue color obtained with chromic anhydride, as the presence of ozone will also produce a blue color with potassium iodide. With water vapor alone no hydrogen peroxide was found. In oxygen and water vapor it was always found, except at extremely low pressure; it was particularly strong in an excess of oxygen at pressures from one-half to one atmosphere. In air and water vapor it was difficult to prove its formation, probably owing to the action of nitrogen oxides. The strongest test was found in an excess of air. As the conditions of cooling, low pressure, and excess of oxygen occur at high altitudes, it is believed that the appearance of hydrogen peroxide in rain is due to electrical phenomena in air.

Radium Content of the Waters at Bath. SIR W. RAMSAY. (*Times,* March 12, 1912.)—The recorded analyses of the Bath waters showed in the main merely ordinary constituents, most of which are present in many drinking waters, and, so far as was indicated by the analyses made at the *Lancet* laboratory, the only unusual constituents were small quantities of strontium and lithium with a trace of bromine. But the fact that many mineral waters all over Europe had for ages past been used for curative purposes, combined with present knowledge that such waters, while of a not unusual "chemical" composition, all agreed in yielding helium, made it interesting to examine the Bath waters for radium and for niton, the emanation of radium. In 24 hours the King's Well gave off 4.927 litres of gas, containing, in 10,000 parts, 360 of carbon dioxide and 9,640 of nitrogen, etc., including 73.63 parts of argon, 23.34 of neon, and 2.97 of helium. In the water of the King's Well there were 0.1389 mg. of radium per million litres. If the niton was represented by the weight of radium capable of forming the niton present in a million litres of water or gas, the figures of the water of the King's Well, the Cross Bath, and the Helting Bath were, respectively, 1.73, 1.19, and 1.70, and for the gas from the King's Well 33.65. The water from the Hospital Natural Baths and from the Crescent Pump Room at Buxton were found by Dr. Makower each to contain 0.83 mg. per million litres, so that the waters from the King's Well and the Helting Bath were more than twice as rich in niton. The Gentlemen's Natural Baths at Buxton contained 1.1 mg. per million litres, or about the amount in the Cross Bath. The gas from the King's Well at Bath contained about four times as much as was contained in the natural gas from Buxton, *viz.,* 7.7 and 8.5 mg. per million litres. It was, unfortunately, impossible to compare these amounts with statements of the radio-activity of foreign waters, for the latter were stated in uncertain units.

The Variation of the Conductivity of a Phosphorescent Body under the Influence of Light. P. VAILLANT. (*Mon. Sci.,* ii, 842, 137.)—The substance observed was calcium sulphide. One of the effects of the current is to polarize the resistance. This polarization is produced slowly, but is very persistent. Another noticeable circumstance is that the resistance of the sulphide increases continuously, independently of all radiation. But the variations in conductivity have no effect on the relative variations which determine the radiant energy. The increase of conductivity which determines the radiant energy is not instantaneous, and three periods can be distinguished in the total variations resulting from a luminosity of given duration and intensity: first, a period of luminosity; second, a period during which the conductivity continues to increase, although luminosity has ceased; third, the period of the decrease of conductivity.

GAS AS AN ILLUMINANT.[1]

BY

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THIS paper is divided into two parts: first, that treating briefly of the historical subject of lighting, and, second, a brief review of the art as known to-day. Attention is entirely devoted to the subject of ordinary gas, as time will not permit of a consideration of special gases, such as Pintsch, carburetted-air, acetylene, etc.

HISTORICAL.

Until the introduction of gas as an illuminant in the early part of the nineteenth century, but little progress had been made in the art of lighting, from the earliest prehistoric days down to that time. The most notable advances so far made had been in the introduction of the sperm candle and the use of the Argand burner with oil lamps. With the introduction of gas, however, a vast stride forward was taken which far outranked all other progress which had so far been made in the art of artificial lighting. In order to appreciate the importance of this discovery it may be well to briefly review the history of lighting up to that time.

The beginnings of artificial illumination go back to the earliest prehistoric days, for when man first made fire he had light, and the old camp fire not only served to cook the simple meal, furnish warmth for the savage, and keep away the wild beasts, but it also gave him sufficient illumination to meet all the necessary requirements of the time. For many centuries burning wood continued to be the only means of lighting; from the bonfire developed the firebrand and the pine torch. Even as late as the days of Homer, the Greeks knew no other light than that of the flaming torch of pine wood. The tourist to-day will still meet in many far-away country houses, for instance in northern Bohemia and in some Alpine districts, torch-holders close to the fireplace for holding the torch. During the long, dull evenings the peasant's hut is lighted only by these crude torches, hewn from pine logs. This form of lighting was used extensively as late as the year 1000, and was frequently provided with a hood and even a chimney for carrying off the smoke.

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[1] Address delivered at the Celebration of the Centenary of the Introduction of Gas as an Illuminant, under the auspices of The American Philosophical Society, The Franklin Institute, The American Chemical Society and The American Gas Institute, in the hall of The Franklin Institute, Philadelphia, on Friday, April 19, 1912.

Going back, however, to a very early period, we find the first step away from the pine torch. Man had begun to recognize the luminous power of animal and .vegetable fat. First, tallow was burned in open dishes. This method of lighting was neither bright nor agreeable, but sheep's and ox's tallow were easily had, and represent the first use of fat for lighting purposes. Later a cotton wick was inserted in the fat or tallow, and we find in the numerous collections of Roman lamps many examples of beautifully chased and carved forms with one or more openings through which the wick protruded. At best, however, the illumination from such a form of oil lamp must have been extremely poor, as judged from modern standards.

The next step in the progress of lighting was the invention of the candle. As early as the beginning of the fourth century, under the government of the Emperor Constantinus, the city of Byzantium is said to have been illuminated with candles on Christmas Eve. No further steps forward, however, were made for many centuries, and even at the end of the eighteenth century tallow and wax candles were made with plain cotton wicks. The greatest drawback to the old-fashioned candle was the fact that the wicks required constant trimming. How modest the demands of our forefathers were is evident from the words of Goethe, saying that he cannot imagine any better invention than that of candles, which would burn without being trimmed.

Another inconvenience of candles was that the fire to light them had each time to be struck with steel and flint, as matches are an invention of the nineteenth century. For obtaining a flame from sparks, wooden sticks with sulphur and chlorate of potassium at one end were invented. To ignite these sticks it was necessary to dip them into sulphuric acid, which, therefore, must always be kept handy. How surprising this invention was to the people of that age is evident from a sentence in Grillparzer's Autobiography, "As often as I take hold of a chemical lighter, a feeling of gratitude overwhelms me, thinking of the time when at night I have tried to strike a light with flint and steel."

The first part of the nineteenth century witnessed a great change in candle manufacture; namely, the introduction of the method of casting instead of that of dipping. This made a much neater candle. The inconvenience of having to trim the candle has been recently done away with by the discovery of the use of boric acid, into which the wicks are dipped. These wicks are plaited with three strands, which spread a little as they burn away, and therefore reach into the hottest part of the flame, where they burn to ashes. By the time the candle had reached this stage of perfection, however, it had long been outrivalled by other means of lighting—first by oil lamps, and then by gas and electricity.

Until the latter half of the eighteenth century little or no change in oil lamps had been made from the shallow vessel with its wick and smoky flame. The oil lamp of Goethe's age differed in principle in nothing from those which have been found at the excavations of Herculaneum and Pompeii. They were very simple: an oil tank with a cotton wick. The greatest trouble with such a lamp was the smoke. In order to provide a sufficient supply of air and prevent smoking, a lamp glass was placed over the flame, a very simple arrangement, but long in coming. In the works of Leonardo da Vinci, who occupied himself, besides his art, with all kinds of engineering and practical problems, we find the plan of a lamp with a glass shade, and probably also a lamp shade, but, so far as we are aware, the plan was never executed. Later the Chevalier Grollier de Severiere designed, in 1675, an oil lamp with wick and smoke exhaust tube, which was intended to both light and heat the study, in which the lamp was placed on a table. Real lamp glasses were invented in 1756 by a Parisian apothecary, Quinquet. Later on a tinsmith in Weisbaden invented the improvement of the constricted lamp glass, by which the whole supply of air is forced into the flame.

In 1784 Argand invented his famous burner, consisting of two concentric tubes, between which was placed a tubular wick.

The inner tube was hollow and permitted a current of air to pass upward, thus supplying the flame with sufficient oxygen for good combustion. A chimney was placed outside, which protected the flame, added to its steadiness, and increased its efficiency.

Early oil lamps cast annoying shadows, due to the fact that the oil had to be kept at the same level as the top of the wick. To overcome this the Carcel lamp was invented, in which the oil was raised to the flame by means of a small pump. Then followed the moderator lamps, in which the oil was raised by means of a special spring. But the entire lamp industry was changed when, after the discovery of petroleum, a thin liquid fuel was used in place of thick oil. In a very short time petroleum replaced almost entirely both candles and heavy oil lamps for general lighting. The petroleum lamp, therefore, represents the climax in lighting by a self-contained light; that is, a light which is supplied and kept by the individual. It is interesting to note, however, that, despite the introduction and use of both gas and electricity, the consumption of both candles and oil lamps is greater to-day than it ever was before.

The introduction of lighting in a community which could be supplied and operated from a central source, with nothing for the individual to do but to turn on the light when he wanted to use it, marks, up to that time, the greatest era in all the history of artificial illumination. It is the advent of this era, one hundred years ago, that we are celebrating at this time. It must not be supposed that the first gas light was made or used only a hundred years ago, but the year 1812 marks the time when the first gas company for supplying the public received its charter and started operations. Prior to that time a number of individuals had experimented with gas lights very successfully. The best known of these are Murdock, Lebon, and Winsor.

In 1792 William Murdock lighted up his home at Redruth, in Cornwall, with coal gas. Being very busy with other things at the time, he dropped the matter until 1797, when he again took up his experiments and lighted his house and office in Old Cumnock, in Ayrshire. The following year, 1798, he lighted Soho Foundry, at Birmingham, in the same way, and from this time on devoted much time to improving his methods of manufacturing and purifying the gas, until in 1802 he gave a public display of gas lighting at Soho, which attracted much attention.

Meanwhile, in 1801, Lebon, in Paris, had lighted his house and gardens in the Rue St. Dominique with gas. In 1803 Winsor carried Lebon's ideas over to London and began to experiment with Lebon's gas apparatus at Hyde Park. The following year he obtained the first English patent for a gas-manufacturing plant, and the same year gave a public display of his gas lights at the Lyceum Theatre, London.

The year 1805 witnessed two important lighting installations—that at the factory of Mr. Henry Lodge, near Halifax, which was installed by Samuel Clegg; and that at the cotton mill of Messrs. Phillips & Lee, at Manchester. The latter was installed by Murdock and comprised nine hundred burners. Shortly after this, David Melville began experiments in this country, lighting his house at Newport, R. I., and taking out the first American patent for coal gas manufacture. In 1807 Pall Mall was lighted by gas, this being the first important installation of out-door gas lights. In 1812 a royal charter was granted to the London and Westminster Gas Light and Coke Company, this being the first gas company formed. In 1816 the first gas company in the United States was incorporated at Baltimore. From this time on the introduction of gas into the different cities of the world was rapid, but their history need not be taken up here further.

BURNERS.

The first burner as used by Murdock consisted of a small iron tube, open at the end. It was very evident, however, that this was both wasteful and smoky, and for it he substituted a closed tube, in which were bored three small holes, giving three divergent jets. This, due to its shape, was called a cockspur burner. It gave less than one candle-power per cubic foot of gas. This, however, was soon followed by the batswing burner, consisting of a thin slot in a convex tip, giving a broad but not high flame. In 1820 the fishtail burner was invented by Neilson, of Glasgow. This consisted of a concave tip in which were bored two holes at angles of about 45 degrees, so that the streams of gas issuing from these holes impinged on each other, forming a flat flame, much less broad than the batswing, but considerably higher. When used with enclosing glassware this was found to be much less likely to crack the same. Both of these forms of burners are in common use to-day. The fish-tail burner, however, is not as efficient as the batswing, unless used with extremely rich gas. The tips used on flat flame burners were made of iron, but owing to their high conductivity they lowered the temperature of the burner and consequently were abandoned and replaced by lava or other forms of heat-resisting, non-conducting material.

In the earliest days of gas lighting the Argand burner, adapted for the use of gas, was standard. This burner was essentially the same as that used for oil, with the exception that no wick was supplied and that at the top there was a thin plate perforated with a large number of holes through which the gas issued, the different flames uniting to form one cylindrical flame. The Argand burner was for a long while the standard burner; but its drawbacks, due to first cost, difficulty in keeping the glassware clean, and the fact that it was extremely sensitive to draughts and had to be regulated as to the correct amount of air admitted, prevented its universal adoption. Although more efficient than the ordinary flat flame, it was superseded by this type in most places. In this connection it is interesting to note that as late as 1819, when Peckstone's "Gas Lighting" was published, meters had not been introduced, and that the method of charging was on the flat rate, which in London was £3 per year for an Argand burner burning from sunset to 9 o'clock at night; £4 per year from sunset to 10 o'clock, etc. This was, according to meter rates, about $3.75 per thousand; but the rate was actually less than this, owing to the fact that there was no guarantee that the customers turned the lights out at the hour agreed upon, and, furthermore, the adjustment of the burners was such that generally much more gas was used than should have been. The first meter was invented in 1815, but it was not for a good many years afterward that their use became universal. The standard meter as ordinarily used to-day was not invented until 1843.

In 1853 Sir Edwin Franklin invented the regenerative burner, which is essentially an Argand burner in which the products of combustion are used to heat both the gas and air supply to the burner. This preheating of the air and gas allowed a high temperature to be obtained, and, inasmuch as the light depends upon the temperature of the carbon particles, a much higher efficiency was obtained by this method. Siemens, in 1879, improved on this, and his type of burner is still in use in certain places, although rapidly being replaced by the inverted mantle burner. It had numerous drawbacks, chief of which was the large size of the units. It was also costly to install, and, with the exception of use in lighting large spaces, was never widely introduced.

Up to the time of the introduction of the Welsbach mantle we find the following efficiencies of the different types of burners on coal gas of 16 candle-power:

Flat flame	from .6 to 2.5
Argand	from 2.75 to 3.2
Regenerative	from 7.0 to 10.0

The regenerative burner could be forced to considerably higher efficiency than this were it not for the inability of the parts composing the lamp to withstand the intense heat. It is to be noted that the Argand burner was the standard used for testing the candle-power of gas, and that gas was supposed to give 16 candle-power, with the proper Argand burner, for every five cubic feet of gas consumed. It is from this London standard that we get the standard 16 candle-power lamp as used in electric lighting.

MANTLE BURNERS.

The entire gas-lighting industry was revolutionized by the invention of mantle burners by Auer von Welsbach, in 1885. It is interesting to note, however, that many attempts along the same lines had been previously made before that time. In 1826 Gurney employed a cylinder of lime on which he played an oxy-hydrogen flame. This never proved a commercial success, although an attempt was made to use a modified form in Paris with oxy-coal gas. Gaillard, in 1848, made a mantle of platinum gauze, but, due to erosion caused by the gases, its life was short, and the plan was never commercially put into practice. The next step was that taken by Bunsen, in 1855, who produced the well-known non-luminous flame by mixing coal gas and air before ignition. Claymond, in 1882, devised a basket or cone of threads of calcium magnesia supported by a platinum wire cage, and by means of a blow-pipe and Bunsen burner heated the same to high incandescence.

In 1885 Welsbach was working on the composition of rare earths as shown by the spectroscope. In order to make them more easy for examination than by placing them on the usual platinum wire, he immersed cotton in a solution of the metallic salts, which, after being burned, gave a replica of the thread, composed of the oxide of the metal, and glowed brightly in the flame. This led immediately to a study of the possibilities of using this process for lighting. Many different kinds of rare earths were tried, but it was finally determined that the most satisfactory combination was that of 99 per cent. of thorium and one per cent. of cerium, and this is the standard in use at the present time. It is interesting to note, in this connection, that if the percentage of cerium is either increased or decreased, the decrease in the candle-power is very marked. If, for example, the cerium be increased to five per cent., the candle-power is less than one-half of what it is at one per cent.; while if ten per cent. of cerium be used, the candle-power has fallen to about twenty per cent.

In a paper of this length it is needless to review the further history of the development of mantle burners, except to state that the inverted burner, as we now know it, was first introduced in the years 1900 to 1901, but was not perfected so that it came into popular use until several years afterward.

MODERN GAS LIGHTING.

Flat Flame Burners.

Flat flame burners are going rapidly out of use, except in special instances where the light is used more for a marker than for the amount of illumination given off, or where the burner is subject to such hard usage as to render the employment of a mantle burner inadvisable. It is to be noted that the rating of flat flame burner tips as ordinarily sold on the American market is of little value, as many instances are found where a tip rated as using one cubic foot of gas per hour gave as high a candle-power as a four-foot tip, with no greater amount of gas consumption.

The flame from an open gas burner appears to be practically transparent to light, as the horizontal distribution curve of such a flame is practically uniform. This is also true of the vertical illumination curve, with the exception of the slight shadow cast by the tip. In other words, the horizontal candle-power, as ordinarily measured, whether in a plane with that of the flame or at right angles to it, practically measures the mean spherical candle-power of such a unit.

Burners of this type are generally used with some form of globe to protect them from draughts. The effect of such glassware is usually to throw considerable light upward, so that where the light is wanted below the horizontal a burner of this type is inefficient as ordinarily employed.

The Argand burner is but seldom used to-day, except for testing the quality of gas, so that we need not here consider its characteristics.

Upright Mantle Burners.

Upright mantle burners have been greatly developed since their first introduction in 1886. In the early days there was a decidedly greenish tinge to the light, and even to-day, in most of the mantles, this greenish tinge is quite noticeable, especially in comparison with other sources of light. This has, however, been more or less rectified, and it is possible to-day to buy mantles on the market which have considerable variation in color. One of the drawbacks to the mantle burner has been that until recently only one size of mantle was available; namely, a mantle about 3½ inches high, giving a rated horizontal candle-power of from 60 to 80. At the present time, however, a smaller mantle is available, so that it is possible to get a wider variation. This has been one of the chief drawbacks of gas lighting as compared with electric lighting; namely, the lack of different sized lamps. Efforts to overcome these objections seem to be making progress in both upright and inverted burners, and it is likely that in the near future this advantage of electricity will be largely done away with.

An important point in gas lighting, especially with mantle burners, is the effect of pressure and also quality of gas on the light. Gas lighting would be much improved were burners selected with reference to this point, the same as electric lamps are selected for different electrical pressures in various districts.

The modern electric central station measures the voltage pressure at different parts of its circuits and buys its lamps accordingly, thereby furnishing proper lamps to the customer. In this way a great deal of complaint as regards poor service, etc., is done away with. If the gas companies followed the same plan they would undoubtedly have a much better satisfied class of customers, which is the best asset a gas company could have. Moreover, in this connection it is interesting to note that mantle burners are seldom or never bought on specifications. When the electric light company furnishes lamps to its customers it is only after the lamps have been bought on rigid specifications and have actually been tested to find out whether or not they comply with the requirements. In gas lighting, however, it is the usual policy of the gas company to furnish to its customers mantles and burners at all prices and grades, leaving the customer to select whatever in his opinion he sees fit to buy. The result is that the poorest and cheapest burners and mantles are most often found on the gas company's mains, resulting in the dissatisfaction of the customer and making him comparatively ready to change to electric lighting when opportunity offers. It would seem that if the gas companies are to retain their customers for lighting purposes it is necessary to take some steps along this line, as, with the introduction of the tungsten filament lamp, the mantle burner—especially under poor operating conditions—can no longer hope to compete as successfully as in the past.

With the upright mantle burner the distribution of light is considerably different from that of the open flame burner, which, as we have already seen, gives practically spherical distribution. The upright mantle burner gives its maximum light on the horizontal and comparatively little light directly underneath. Practically one-half the light is above the horizontal and one-half below. From the standpoint, therefore, of ordinary lighting, it is desirable to change its distribution. The ordinary shades as used with the mantle burner often accomplish their purpose of diffusion more or less successfully, but fail to redirect the light in directions below the horizontal. As a matter of fact, most upright burners, when equipped with diffusing glassware, throw two-thirds of their light above the horizontal, and, unless the walls and ceilings be extremely light, a large amount of flux is lost. No distribution curves are given in this paper, as such are easily available elsewhere, in articles mentioned later. The thing to notice at this point is that the upright mantle burner is, generally speaking, not well adapted to utilize most of the light.

Inverted Mantle Burners.

Lamps should be rated in terms of their total flux rather than their mean horizontal candle-power, if we are to obtain comparative figures. From an illumination standpoint the important things about a lamp are the total quantity of light given out and the distribution of the same. The importance of this was not realized in the gas world until the introduction of the inverted burner. The standard inverted burner gives about 67 per cent. of its light below the horizontal and 33 per cent. above. This should be compared with the standard upright burner, which gives 55 per cent. above and 45 per cent. below. This means, for the same total flux of light, an increase of nearly 50 per cent. in the light below the horizontal, which, if this is taken as the useful light (as is often the case, but not by any means always), marks a great increase. Moreover, any glassware which is used with inverted burners is apt to increase rather than decrease the flux below the horizontal, especially if the glassware is of the open type; so that at the very start we have a marked increase in the net efficiency of the inverted as compared with the upright burner. In addition to this, the burner itself is slightly more efficient. Owing, furthermore, to the fact that the inverted burner lends itself more easily to artistic uses and is less likely to blacken the ceiling, as it can be placed lower, its introduction and use have been very rapid. With the introduction of this type many new kinds of glassware have been devised for it. Among these may be mentioned those of the prismatic type which are now available with the standard inverted mantle burner so as to give the three typical distribution curves—extensive, intensive, and focusing—which are found to fit the requirements of so many installations. The difficulty of breakage in connection with the use of pressed glassware has been largely obviated by the use of a metal collar. We can therefore safely state that with the improvements which have already been made it is possible, with gas, to duplicate nearly all of the effects which can be obtained with electric lighting, both as regards ornamentation, distribution, ease of control, etc., and even surpass it in cheapness of operation.

Gas Arc Lighting.

The gas arc has been an attempt to obtain a large unit of high candle-power where a large flux of light is wanted. Owing to the size of the unit it has generally been thought to be highly efficient; but, due to causes which it is not necessary to enumerate here, it may be stated that the gas arc is no more efficient—if as much so—than the individual burner. We can therefore consider a gas arc to be nothing more or less than a large upright or inverted burner, and most of the remarks which have already been made as regards these two types can equally well be applied to the gas arc.

DIFFUSION.

One of the most important considerations in connection with mantle burner lighting is that of diffusion. When our only forms of burners were those of the Argand or open flame type, the necessity of diffusion was not great, as the candle-power per square inch was not in excess of five. With the introduction, however, of the mantle burner, with an intensity of many times this, and in addition a much larger quantity of light, it became necessary to shield the eye not only in order to protect it from harm, but also that the eye could be able to work with a wider pupillary aperture, and thus be able to see better. It is recognized now as one of the fundamental principles of good lighting that the light must be well diffused, and it is interesting to note that the passing of the bare mantle burner is becoming exceedingly rapid.

HIGH-PRESSURE GAS LIGHTING.

The ordinary pressures as used in gas lighting are from one-half of an inch at the burner up to, perhaps, two inches. Flat flame burners work best on comparatively low pressures, but with the mantle burners higher pressures are more suitable. It was soon found that an increase in light could be obtained by using higher pressures. For street lighting, therefore, it was logical that experiments should be made along these lines. The result has been the introduction of high-pressure gas burners principally for street lighting. With the ordinary low pressure in either the inverted or upright burner the candle-power per cubic foot is in the neighborhood of 20, whereas with high pressure this can be increased 2 to 2½ times. High pressure is adapted for either upright or inverted lighting; but, owing to the superior distribution obtained with the inverted type, this is rapidly supplanting the upright type. One of the most notable installations of this kind is in Berlin, where lamps rated at 4000 candle-power are employed, consisting of three mantles operating at a pressure of 50 to 60 inches of water and consuming about 25 cubic feet of gas per mantle, or 75 to 80 cubic feet per hour. It is interesting to note that the curve of distribution in the high-pressure burner is somewhat flatter than in the ordinary inverted low-pressure burner, a point particularly well adapted for street lighting.

Conditions being considerably different in this country from those abroad, it has not been adopted to any extent here, although it is likely to have a much wider use than at present. Owing to the extreme intensity of the mantle it would seem necessary to adopt some means for diffusion, and, although this is not as important in street lighting as in indoor work, it undoubtedly will soon become one of the first requirements.

HEAT CONSIDERATIONS.

The scope of this paper will not allow us to consider this question in detail, but it is sufficient to call attention to the fact that, while more heat is liberated from the production of light by gas than by electricity, it seems to be the consensus of opinion of those who have thoroughly studied the subject that such heat is useful in producing a ventilation which would be otherwise unattainable, and the products of combustion are carried off by this means, so that the quality of the air in a room is at least equal to that when other forms of lighting are used.

METHODS OF GAS IGNITION.

The ordinary method of lighting gas is by striking a match, but, owing to this inconvenience, many different schemes have been adopted. The most common of these is the pilot light, consisting of a by-pass which allows a small quantity of gas to pass around the burner. This pilot light burns continually, and, whenever the main supply of gas is turned on, lights the mantle. The gas can be turned on either by turning the gas cock by hand or else by a pneumatic valve control. In this latter case a very small pipe is run to any convenient point, and at the end is attached a pneumatic plunger. When this is pushed in, air is forced through the pipe and turns the main valve in the gas supply pipe. In order to turn the light off, the plunger on the wall is pulled out, resulting in the valve in the gas supply pipe being thrown the other way. When properly installed the pneumatic control system is well adapted for this purpose, and does for the gas what the electric switch does for electricity.

Another method of ignition is that by the jump spark system, which has been in use for many years. By this system, when a button on the wall is pressed the gas is turned on and at the same time a spark ignites the same. The latest form of this is self-contained in the fixture.

Still another method of ignition is by a catalytic process. Advantage is taken of the well-known quality of platinum sponge to occlude gases. This is placed on the mantle, and when the gas is turned on the platinum sponge begins to glow and rises to a sufficient temperature to ignite the gas. Many efforts have been made to introduce this form commercially, but, up to the present time, not very successfully. Other chemical means have been introduced, such as an iron-ceria compound, but it is too early yet to state how successful this will be for this purpose.

GENERAL.

To one familiar with what has been accomplished in this field one of the most astonishing things in the gas situation is the lack of standardization. It is true that a good deal has been accomplished along this line within the last year or so, but there is still much to be desired. The writer would suggest some of the following steps to obtain improvements in gas lighting:

1. Greater range in the size of the units to better meet the

requirements of all classes of light, both in upright and inverted burners.

2. More reliable methods of commercially rating gas lamps so that when specifications are drawn up by the illuminating engineer or the architect giving certain definite illumination requirements, he can be reasonably sure of obtaining exactly what he wishes.

3. The lamp should be standardized similarly to the present methods of standardization of electric incandescent lamps.

4. Holders or fitters should be changed to conform to electric practice. Thus the gas fitter is 3⅝ inches in diameter; whereas the standard electric is 3¼ inches. Two-and-a-quarter-inch holders are common to both gas and electric.

In a paper of this length it is impossible to more than very briefly sketch the historical and present state of the art. Lately much has been published on this subject, and the writer would refer to the excellent papers on gas lighting appearing in the Johns Hopkins Lecture Course of the Illuminating Engineering Society, volumes 1 and 2. For different forms of photometric curves, for both upright and inverted burners, reference is made to "Practical Illumination," by Cravath and Lansingh. A complete bibliography of the subject is to be found in the lectures on gas lighting in the Johns Hopkins Lecture Course referred to above.

Pulverization of Metals by the Alternating Oscillating Discharge. ANON. (*Rev. Sci.,* xv, 1466.)—The metallic electrodes used to produce the oscillating discharge of a condenser are pulverized. A powderable quantity of metal is pulverized; thus, 1,000 discharges occurring between two gold spheres of 1 cm. diameter at a distance of 1.6 cm. pulverized 6 mg. The principal laws of this phenomenon were established by Kowalski and Banasinsky. For each metal the quantities pulverized at each discharge are very constant, and only differ by 1 or 2 per cent. at the maximum. But these quantities vary for each metal. For some metals for which this phenomenon has been observed the order of the magnitude of the pulverization is gold, platinum, zinc, iron, copper, silver, and aluminum. The pulverization increases with the explosive distance. Under equal conditions the weight of gold pulverized at 0.6 cm. was 1.9 mg., and at 1.6 cm. it was 6 mg. The pulverization diminishes as the capacity of the condenser diminishes, and this diminution is greater for large explosive distances than for smaller ones.

Electric Smelting of Zinc-Lead Ores at Sarpsborg, Norway, and at Trollhattan, Sweden. J. C. MOULDEN, and F. W. HARBORD. (*Chem. Eng.*, xiv, 510.)—The ores to be treated are complex sulphides, Broken Hill slime, and mixed sulphides of lead, zinc, copper, and iron, which have hitherto but little commercial value. The furnace has carbon electrodes, one in the bed and the other removable through the roof, and the smelting is affected by resistance with low voltage currents. The capacity of the furnace is 3 tons; its rate 2.8 tons of roasted ore per 23 hours at a horse-power of 350. The charge consists of roasted ore, coke or anthracite dust and flux, and the yield is crude spelter, zinc-lead powder, afterwards recharged, silver-bearing lead, a copper iron matter containing zinc and silver, and slag containing a little lead. Tests were run for a period of 27½ days at Trollhattan, in which were smelted 518 tons of Broken Hill slime, 19 tons of calamine, 22½ tons of zinc-lead powder, and the products were 161 tons of crude zinc, 2½ tons of lead, 36 tons of powder, and 17 tons of lead, which had leaked through the porous material of the furnace, and 9 tons of zinc-silver-lead skimmings. This means 64 per cent. of the zinc, 74 per cent. of the lead, and 46 per cent. of the silver. It is believed the yield can be made to reach 75 per cent. of the zinc, 80 per cent. of the lead, and 80 per cent. of the silver; and on this basis the profit would be about $7.50 per ton of slime, with slime at $14.15 per ton at Broken Hill, freight $11.25, cost of treatment $7.60, and electric heat at Trollhattan costing $7.50 per horse-power year, and the cost of calcination at Tyse at $3.50 per horse-power year.

Nickeled Gas Reflectors. R. W. WOOD. (*Astrophys. Journ.*, xxxiv, 404.)—It is well known that silver surfaces absorb a large proportion of the ultra-violet radiation which may fall on them, and this fact is of importance in any researches depending on the detection of short wave-lengths in various light sources. Recent experiments suggested the suitability of nickel for this purpose, and this paper gives directions how to ensure an even deposit of nickel on the surface of a glass mirror. The best results were obtained by electrical deposition from the double sulphate of nickel and ammonia. To illustrate the action of the nickel a set of photographs are given, showing the relative amount of ultra-violet radiation reflected by mirrors of various metallic films.

The Permeability of the Envelopes of Balloons by Hydrogen Gas. M. JULHE. (*Mon. Sci.*, lxxvi, 844, 285.)—Hydrogen is dissolved in the caoutchouc of the envelopes, which allows it to escape to the outside, as ammonia escapes from an ammoniacal solution. To avoid this inconvenience, the rubberized material should be lined on the inside of the balloon with an envelope impregnated with a solution of gelatine in glycerine.

FUNDAMENTAL CHEMICAL CONSTANTS.[1]

BY

PROF. EDWARD WILLIAMS MORLEY.

A MAN indulges in scientific research because it is fascinating. It gives more pleasure than golf; and, to have added to it so delightful a recognition as that given to me to-night, both in the medal and certificate, and also in the words introducing me, adds much even to the delight of successful research.

It was suggested that my topic should discuss the fundamental constants of chemistry. The importance of physical constants is, largely, that one of them holds condensed in small volume the essence of many observations, perhaps of all the observations which have ever been made in a given line. We have followed the motions of the planets with accurate observation for two hundred and fifty years. The number of observations is very great; the labor of consulting them would be enormous. But all their value has been extracted and condensed in a system of constants, seven for each planet. All planetary positions are wrapped up in these constants; from them, positions for the future can be unfolded as desired, with an accuracy corresponding to the accuracy with which the constants are known at a given time. A constant is compressed knowledge; it is like a seed, ready to grow and bud and blossom and fruit. The constants of chemistry are not so intricate as those of astronomy, and the labor of establishing them, although considerable in some cases, has not been so great as in the case of astronomy.

Chemical constants vary in nature and importance, and vary in their interest for the man who is not a chemist. Some are like words in a dictionary or figures in a mathematical table. It is needful that such constants be determined and tabulated, in order that a call for any one of them may be answered without delay and waste of time. For instance, a scientific man at present is endeavoring to find whether the properties of a compound are functions of the changes of energy taking place in its formation from its elements. To examine this matter, he will need to know the melting point and the boiling point and the critical temperature of some well-known elements and of their best-known compounds. Then he will doubtless need to know the density of each, in the solid form, and the liquid and the gaseous; and then greatly to enlarge this list of measurable and well-determined properties. If most of these constants are already determined, he may be able to enrich our conceptions of the nature of the material universe within some short time; if they are not ready for him, he cannot find what he desires, and the world will be the poorer.

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[1] Presented at the Stated Meeting of the Institute, Wednesday evening, May 15, 1912, when Prof. Morley received the Institute's Elliott Cresson Medal.

Some chemical constants are tools with which to increase human comfort, or human wealth, or the effective power of human effort. The knowledge of some thermal constants of certain steels enables us to add immensely to the strength and durability of steel constructions under strain,—to double or quadruple the strength of a crank shaft.

Other chemical constants are poems, or prophecies, or histories. It is of such constants that I wish to speak. They show us something about the nature of matter, which is the most interesting thing in the world, except human nature with its varied expressions. Excepting the study of human nature, the study of the nature of matter is the most fascinating subject open to us.

The fundamental constants of chemistry are the atomic weights. These were first investigated in order to fill up the pages of our dictionary. They were further studied in order to increase the effective power of human effort, as tools in analytical processes. But, while these constants were obtained for these prosaic ends, we find, to our great delight, that they perform the added service of assisting somewhat our insight, limited as it is, into the nature of matter.

About a century ago, Prout announced the theory that all atomic weights are integral multiples of the atomic weight of hydrogen. For example, the atomic weight of lithium is nearly equal to seven. Prout asserted that, when it is determined with final accuracy, the number will be *exactly* seven, and not nearly seven. So the atomic weight of carbon is about twelve, and that of oxygen about sixteen. Prout asserted that these numbers, when exactly determined, will be the exact whole numbers, twelve and sixteen.

The suggestion was a valuable one. It stimulated some of the best work which has been bestowed on atomic weights, and was well worth the great labor which it has stimulated. It was a long time before results were obtained sufficient to settle decisively the matter. One early result caused a modification of the theory. The atomic weight of chlorine was found to be not a whole number, but a number nearly equal to 35.5. The result of many most rigorous and exhaustive experiments gives the value 35.45, when oxygen is taken 16.00; accordingly, Prout's hypothesis was modified to assert that, when finally determined, it will be found to be exactly 35.50, an integral multiple of *half* the atomic weight of hydrogen. Subsequent modifications of the original theory assume the fourth or even the eighth part of the atomic weight of hydrogen as the basis.

If the theory were known to be true, it would allow an immense saving of labor. For instance, in determining the atomic weight of oxygen, if we were authoritatively informed that it must be either 15.50 or 16.00 or 16.50, we need only to make experiments rigorous enough and numerous enough to show that it is more than 15.5 and less than 16.5. Instead of the difficult process of *measuring,* we merely have to use the simple process of *counting*. Measuring must always be attended with errors, which cannot be eliminated except in part, and the avoiding of errors and the reducing of errors till they are negligible is a long and difficult process. But counting is affected, not with errors, but with blunders, and blunders can be avoided. In case of objects like atoms, which we cannot see, counting has to be effected by weighing; but a hundred sovereigns can be counted by weight without seeing the individual sovereigns, and can be counted with absolute precision by weighing with an accuracy of one-fourth of one per cent. But to pay out the same value of uncoined gold, we must weigh to the hundredth part of one per cent. So, if Prout's hypothesis were known to be true, an accuracy of one or two per cent. would show that the truth was 15.50 or 16.00; while, if the hypothesis cannot be assumed for our guidance, an accuracy of one-hundredth of one per cent. is barely sufficient. So, if the theory were proved to be true, it would permit an immense saving of labor from the time it was adopted as a guide, but there is a more interesting result from the truth of the hypothesis. It suggests a theory of the structure of matter. It suggests that the atoms of many elements, perhaps of all, consist of the same identical matter put up in packages of different weight. Hydrogen consists, according to one form of this theory, of two ultimate particles so adhering to each other that they are never separated in any chemical process known to us. Carbon consists, according to the theory, of twenty-four such ultimate particles, so held that chemical forces cannot separate them. So with oxygen, consisting of thirty-two; so with chlorine, consisting of seventy-one.

There has been much difficulty in determining atomic weights with a degree of accuracy sufficient to pronounce upon Prout's hypothesis. Even when they are determined as accurately as is now possible, some difficulty remains, at least in some minds, for many of the well-determined atomic weights were found to be curiously near to whole numbers. Perhaps the most serious difficulty, for a long time, was that we did not know the atomic weight of oxygen with sufficient accuracy. It so happens that most atomic weights are determined, as a matter of fact, by experimental comparison with oxygen, sometimes directly and sometimes indirectly. The atomic weight of carbon is determined by direct comparison with oxygen. Experiment shows that twice sixteen parts by weight of oxygen combine with twelve parts by weight of carbon. If, for the present, we assume sixteen as the atomic weight of oxygen, twelve is obviously the atomic weight of carbon, determined by direct comparison with oxygen. The atomic weight of potassium is determined by an indirect comparison. Five times sixteen parts by weight of oxygen combine with twice 35.45 parts by weight of chlorine, and 35.45 parts by weight of chlorine combine with 39.15 parts by weight of potassium, so that 39.15, by this indirect comparison, is the atomic weight of potassium.

Since oxygen is thus used as an intermediate term of comparison in most cases, we see that, in order to determine whether a given atomic weight is a multiple of the atomic weight of hydrogen, or of half of the same unit, we need to know with accuracy the atomic weight of oxygen referred to the same unit. To determine it has been difficult. Dumas, in a piece of work which will long be regarded as a classic of science, about the year 1842, made a series of determinations by the best method known at the time. As he was finishing the work, there was detected in his laboratory a source of error attending all his experiments. He expressed the hope that his results were within the two-hundredth part of the truth, and his judgment was wonderfully accurate, for his final result was just the two-hundredth part too large. This result could by no means determine whether the atomic weight of oxygen is the whole number sixteen or is a tenth of a unit more or a tenth of a unit less. This same range of uncertainty becomes more troublesome in the case ot larger atomic weights; it amounts to a quarter of a unit in the case of potassium.

To determine whether Prout's hypothesis or some of its modifications is true, it became necessary to determine the atomic weight of oxygen with far greater precision than attained by Dumas. It was found impossible to utilize the method of Dumas; although several of its sources of error can be removed, the annoying retention of water by the copper reduced from its oxide in the experiment could not be avoided in a workable apparatus. Using methods devised for the purpose, hydrogen was prepared containing less than 1/200,000 part of impurity. That is a simple matter to mention, but it took many months to accomplish! The proving that the impurity was as stated took six months, and required more invention than a little. Next, oxygen was prepared, of corresponding purity. That was really easy. These two were then separately weighed, were combined to produce water, and the water was weighed. The weight of oxygen used divided by that of the hydrogen used gave the atomic weight of oxygen. The weight of water produced divided by that of the hydrogen gave a second value of the atomic weight of oxygen. The fact that these two determinations agreed showed that there was no source of important error in the experiment.

To confirm the result obtained, the density of hydrogen was compared with the density of oxygen, and the ratio of the volumes in which they combine was determined. Multiplying these two ratios together, we secure a new determination of the desired atomic weight. For determining the density of hydrogen, no method heretofore used was found to be sufficiently accurate. A process was invented, in which hydrogen was absorbed in palladium and sealed up in a glass vessel. Globes holding forty litres were exhausted and sealed up by fusion. Then the hydrogen, sealed up by fusion in one vessel, was introduced into the sealed globes, without opening them to the air, after which vessel and globes were left sealed by fusion. Weighing the vessel before and after, we learned the weight of the hydrogen used in the experiment; measuring the temperature and pressure of the hydrogen in the globes, we had accomplished the determination of the density of hydrogen without the use of stop-cocks, which leak, and without introducing any impurity into the hydrogen derived from apparatus through which it is passed. The density of oxygen was easily determined by usual processes, carried out with many precautions to ensure precision. Now, if it were true that two volumes of hydrogen combine with one volume of oxygen, the ratio of the densities would be the ratio of the atomic weights. But it is not precisely true that two volumes combine with one; we had, therefore, to determine what the accurate ratio is, and then correct the ratio of the densities. Since the value thus determined agrees with the two previously found, and since all three agree much nearer than to one part in ten thousand, we are entitled to feel much confidence in the mean result. This value is 15.879.

I am moved to mention a little matter which shows how a scientific man tries to keep himself free from unconscious bias. The determination first mentioned consisted of twelve experiments, in three or four series. In order not to be biased, the results were not computed from the weights observed, until the experiments were all completed. When you test the accuracy of the sights of a rifle, it is well to fire the string of shots without inspecting the target; then it is made sure that one does not unconsciously draw a bead differently on learning of the ill success of the previous shot. So, also, the agreement between the result of the synthetical experiments and those on densities was not known to me till the manuscript had been accepted for publication by the Smithsonian Institution; after that time, I went to Washington and completed the computations and first knew how well the two results agreed. The scientific conscience is rather rigorous.

This fundamental chemical constant is, I think, somewhat more than a figure in a mathematical table, or than a tool to facilitate analyses. It tells us something about a long-discussed question, and asserts a proposition concerning the nature of matter. The atomic weight of oxygen is not exactly sixteen, not 15.50, nor 15.75. Prout's hypothesis finds no support in the most carefully determined atomic weight of oxygen, the only weight which up to that time had been determined by direct comparison with hydrogen, and a determination in which no source of important error has been suggested.

Further, now that we know the atomic weight of oxygen, we are ready to compare other atomic weights with that of hydrogen. If the atomic weight of oxygen is 15.88, then the atomic weight of carbon becomes 11.93, and that is not a whole number, nor a number ending in the fraction one-half, nor one-quarter, nor three-quarters. The atomic weight of chlorine, now that we know the atomic weight of oxygen, becomes 35.18, and that of potassium becomes 38.82; neither of these numbers is in accord with Prout's hypothesis. There are two other well-determined small atomic weights which equally fail to support the hypothesis in question. The onus of proof lies with small atomic weights. If we imagine, for the sake of argument, that the atomic weights best determined are liable to an error of one part in a thousand it is obvious that a small atomic weight, like that of carbon, is liable to an error of not more than a hundredth of a unit, which still leaves its evidential value uninjured. But an atomic weight like that of lead, which is over two hundred, is liable to an error of two-tenths of a unit, from which no conclusion could be drawn as to Prout's hypothesis. The small atomic weights which are well determined utterly fail to support Prout's hypothesis. So far as chemical methods now known can throw light on the matter, Prout's hypothesis cannot be true.

I presume that it will still have its adherents. One cannot but wish that the theory had been true, even when he admits that no modification of it which is consistent with sound physical principles has any support in the facts. Ingenuity can still modify the theory, and can make a modified theory which could not be disproved by experiment. We might assert that all atomic weights are integral multiples of one-hundredth or one-thousandth the atomic weight of hydrogen. That is like striking a ship to escape capture; the ship is no longer of service. A child, learning that ten dimes make a dollar, and knowing that a bank sometimes pays out five dollars in the form of a rouleau containing fifty dimes, might form the whimsical theory that all our silver coins consist of the proper numbers of dimes compressed till they adhere. He may imagine that a half dollar consists of five dimes, hammered together, and a dollar of ten, which retain their identity and could conceivably be separated, though perhaps somewhat flattened and defaced. If, now, the child learns that a dollar weighs more than ten dimes and a half, he may, if the theory has become attractive to him, form a modified theory, according to which the dime is made up of two half dimes, compressed and adherent, and the dollar of twenty-one half dimes. If he next learns, by more accurate weighing, that the dollar weighs as much as 10.82 dimes, he may say that the number really is 10¾, and that the dollar is made up of forty-three quarter dimes. He might equally well say that it is composed of fifty-four fifths of dimes, or of sixty-five sixths of dimes; there is no end of possible suggestions, if he must maintain his early belief without evidence or in the face of evidence.

But civilization and science tend to put away childish things. The humble efforts which you have this evening rewarded with the Elliott Cresson Medal have been efforts to obtain evidence on a most attractive but illusory theory. It is delightful to know that the work of J. J. Thomson and others in a new field affords a more promising basis for speculations on the nature of matter, and so takes away our regret that the theory of Prout has given only negative assistance in that inquiry.

Density of Aluminum. ANON. (*Amer. Mach.*, xxxvi, 10, 388.)—Owing to the high purity of commercial aluminum of the present day, as compared with that on the market several years ago, at which time the density and coefficient of linear expansion of the metal were determined, these data were re-determined by Dr. F. J. Brislee, who reported his results at the sixty-first general meeting of the Faraday Society. The metal used contained aluminum 99.5 per cent. and about 0.25 per cent. each of silicon and iron. The density of cast metal was 2.708, that of hard-drawn rod was 2.705. Remelted aluminum had a density of 2·68, perhaps due to absorbed nitrogen. The coefficient of linear expansion of hard-drawn aluminum is:

$$Lt = L \quad (1-0.00002432\ t),$$

and for annealed aluminum it is—

$$Lt = L \quad (1-0.00002454\ t).$$

The figures given above for density are much higher than that usually ascribed, 2·583, as is also Dr. Seligman's 2.727 for the density of rolled aluminum sheets.

RECENT DEVELOPMENTS IN THE ELECTRICAL ART.[1]

BY

PROF. ELIHU THOMSON.

I APPRECIATE very highly the honor done me in the award of the Elliott Cresson Medal, and return my sincere thanks for the recognition accorded me. It may not be known to all present that my work in the electrical field virtually began within these walls and in this Hall. As a very youthful member of the Institute it was my privilege to take an active part in its work, beginning nearly forty years ago. At its exhibition in 1874, in the old freight depot at Thirteenth and Market Streets, the site of the present Wanamaker store, I was chosen one of the judges of awards in the class of optical, electrical, and scientific instruments. Appointed to deliver a course of five lectures on electricity early in 1877, in this very hall, I am happy to recall that the members were good to the youthful and untried lecturer, and filled the hall each evening. Serving with Prof. E. J. Houston and others on its Committee on Dynamo Electric Machines in the winter of 1877 and 1878, we were able to secure, for the first time, scientific data, voltage, resistance, current, illumination, efficiency, etc., on several dynamos for arc lighting and the single arc light which they each furnished.

The report of the committee appeared in the JOURNAL in 1878. When I left Philadelphia to go to New England in 1880 I had served on the Board of Managers of the Institute for some years.

It is then with a peculiar sense of gratitude and satisfaction that I receive this recognition of my work.

I have been asked to address you on this occasion on "Recent Developments in the Electrical Art." The applications of electricity now cover such a wide field that even to give a fair list of them would be a tax on your patience. Moreover, the term "recent" admits of great latitude, as the whole art is indeed recent. I shall use the word in a somewhat more restricted sense.

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[1] Presented at the Stated Meeting of the Institute, Wednesday evening, May 15, 1912, when Prof. Thomson received the Institute's Elliott Cresson Medal.

But before referring to any recent advances I hope I may be pardoned for recalling, on this occasion, a few incidents besides those to which I have already alluded. My prime object in the course of five lectures given by me in this Hall thirty-five years ago was to show that electricity from any source was in essence the same, and so help to break down the barriers then existing in many minds between static electricity, dynamic, voltaic, thermo, and magneto electricities. Not to enter into details, I may state that at one of the lectures, in preparing my apparatus in this Hall to show that static or high-tension electricity could be converted into dynamic or low-tension currents, the result of the experiment first suggested the possibility and method of my latter invention of electric welding.

In the fall of 1878 I built a special dynamo, and a laborious piece of work it was for a foot lathe. It was used in conjunction with Professor Houston in lectures and demonstrations before the Institute. In fact, the machine was first tested and operated in this Hall. It was in some respects a unique machine, being either a self-exciting, alternating-current dynamo or a direct-current machine at will. As an alternator its winding made it two-phase, or biphase. Its voltage, by coupling its windings, could be varied in the ratio of one, two, and four. Its field could be similarly varied, so as to increase the range of variation, and it required three- or four-horsepower to drive it. In this Hall, and along with this machine, transformation with induction coils was experimented with. Such coils are now called transformers. This was in January and February, 1879. It may be interesting to note that, probably for the first time in the art, two transformers were used with their finer wire primaries connected in parallel to the dynamo line, while the coarse wire secondaries at lowered voltage supplied the work current. This is the arrangement now so extensively used in practice.

It was here, also, and at about the same time, I received my first heavy electric shock from an induction coil stepping up the current of the dynamo to about 10,000 volts. The convulsion threw me back and drew the wires from my hands. The accident certainly taught caution.

The working of this early dynamo, which machine, with other apparatus, is now preserved in our collection of early models at Lynn, Mass., was indeed the means of forming business affiliations which later led to developing the Thomson-Houston arc lighting system, on which the large business of the Thomson-Houston Company at Lynn, Mass., was later built. This company having extended its business into railways, motors, incandescent lighting, etc., it was consolidated together with the Edison General Company, into the General Electric Company, in 1891.

In the early years of the art there was so much unknown that highly important discoveries and inventions followed each other at close intervals. Nowadays, this is not to be expected. The technical progress of to-day consists largely in the refining of methods, increasing efficiencies, improving construction, reducing costs, and extending the range of uses into new fields, while providing for the rapid growth of the industry in lighting, power transmission in all its varied phases, railways, electric heating and furnaces, electro-chemistry, and metallurgy.

Still, these later years are not without their technical triumphs in discovery and invention. The Edison carbon filament lamp, the influence of which on the growth of industrial electricity has been stupendous, was not known till the close of 1879. Improved in minor details, it remained for upwards of a quarter of a century without a rival for small units of light; the improvement coming by the substitution of tantalum and then of pure tungsten for the carbon; the gain in efficiency with the latter was such that approximately one-third of the energy would give as much light, and of a whiter and better quality. Tungsten had long been known in an impure state and in its compounds, and it was used as a component of special steels. Pure tungsten, as at first produced, was found to be a hard, glossy, brittle metal, absolutely without ductility or malleability in the cold, yet by careful research and persistent effort methods were found which at last yielded wire which could be drawn cold.

This was done in the research laboratory at Schenectady, and drawn tungsten wire filaments are now the standard. The unyielding brittle metal has been made so tractable that a single length of over three miles of wire, of a diameter less than that of a human hair, has been drawn. Tungsten drawn wire has the extraordinary strength of 600,000 pounds to the square inch of section. Ductile tungsten is now found to be superior to platinum for electric contacts, and far less expensive. It is also the ideal material for the targets of Roentgen-ray tubes, not yielding where platinum would be melted rapidly in forcing the tube for the purpose of shortening the time of exposure in radiography.

Has the tungsten lamp reached the limit of its development? Certainly not. The knowledge gained in the past year or two renders probable a further advance in efficiency of lamps; leading to the confident expectation that more than 50 lamps of twenty candle-power each may be obtained from an expenditure of only one kilowatt of energy, or about 40 such lamps to the horsepower. These results may possibly be much exceeded, for the research laboratory is not yet through its work.

In recent years, as with incandescent lighting, electric arc lighting has been completely revolutionized. For a long time the arc between carbon electrodes was relied upon solely. It was at first open to the air—the so-called "open arc." Later the enclosed arc or carbon arc with a restricted supply of air served to minimize the consumption of the electrodes, but at a sacrifice of efficiency of light production.

Recently, we have seen the introduction of the various forms of flame arcs, luminous arcs, and the mercury arc lamp with its greenish light. By loading the electrodes of an arc with mineral or metallic compounds the main source of light is the flame between the electrodes, and not, as in the carbon arcs, the hot ends of the carbons themselves.

Many of the streets and open spaces in our large cities are now lighted by magnetite arcs, so named because the electrode which furnishes material to the arc is composed principally of magnetic oxide of iron, mixed with other substances destined to improve the color, steadiness, or efficiency. Development in this field is still going on actively. The characteristic arc light dynamos of former years are now seldom built. Mercury rectifiers instead convert into direct current the alternating currents from constant-current transformers, which in turn receive energy from the general supply mains extending from the great electric stations, which mains supply energy for incandescent lights or motors, and for other uses.

The tendency is now to generate in the station but one type of current, and supply all needs therefrom. A three-phase, alternating-current supply, working through rectifiers, transformers, converters of various types, gives electrical energy in any form and at any voltage required. Thus the Fisk Street Station in Chicago has a capacity of 160,000 horsepower, and in it the three-phase, steam turbine dynamo units range up to 27,000 horsepower each, all varieties and conditions of load partaking of this enormous output.

While, in the early days of electric stations, lighting was the only load, it was foreseen that the distribution of power would eventually become of great importance. In recent years the application of electric motors has made enormous strides. They are fast becoming a universal adjunct to moving machines, replacing all small stationary steam engines and gas engines. Electric motors have already become a component part of machine tools and of many other machines formerly driven by belts from line shafting.

Perhaps, however, no better example of recent progress can be found than a modern high-tension transmission system, for it may combine within itself all of those features which have made electricity such an important factor of our later civilization. In such a transmission system there may be several generating stations far apart tied into the lines or net-work for conveying the electrical energy. In these stations water-power may be used to drive the dynamos, or steam, or both, or even internal-combustion engines may exist.

As generated, the electrical energy is too low in voltage for long-distance transmission. It may be, say, at only 2,000 volts while the transmission requires 100,000. In fact, a plant has recently been put into operation in which the line voltage is as high as 140,000. To obtain this increase of pressure the station current is "stepped up" by giant induction coils or transformers receiving the 2,000-volt current in their primary coils and delivering to the line 100,000 volts from their secondary winding.

Accurate instruments measure the output in amperes, volts, watts, and other factors. In the large stations the manipulation is often by a system of "remote control" whereby, by means of electric relay apparatus, outputs of many thousands of horsepower are controlled by a single person operating push-buttons or small master switches. Here, also, signals and instruments exist for showing him the operating conditions of the plant at any time. Telephones connect the various stations, and parts thereof, over hundreds of miles. Automatic lightning arresters, fuses and circuit-breakers are on guard in case of accident.

Sets of line wires of copper or aluminum, three wires in each set, lead off into the far distance from these great stations, and are supported on high-tension insulators, which are sustained on poles, or upon tall towers of latticed steel. These lines are very much alive. They are dangerous to approach; for the kind of electricity they carry is second cousin to the lightning, for it can jump spaces of many inches. If we follow such a line we may find that it leads to a substation near a town, or to a group of factories, or to a substation power-house operating a railway or a mine. Here it is " stepped down " by reversing the process which gave the energy its high pressure. Step-down transformers reduce its voltage to a more manageable amount; perhaps to again about 2,000 volts. These transformations have caused but small loss, for the efficiency of the large transformers is but little less than 100 per cent. We find again, in the step-down station, the measuring instruments, automatic apparatus, and appliances for control. And now lines lead off in various directions carrying the 2,000-volt current, some of which is finally again transformed down, perhaps, to 100 or 200 volts, for low-tension supply on the consumer's premises, where his electric meter registers the amount of energy used by his lights, his motors, and the like.

Part of the energy may, through rectifiers, supply the current for the arc lights on the streets or in the stores. Vacuum-tube lights even may be operated. Electricity has given us sufficient variety in our means for producing light. Another part of the energy may be changed, by machines called rotary converters, and adapted to the operation of railway car motors, which need a direct current of about 600 volts.

Still another fraction may work apparatus employed in changing large storage batteries, or may be further divided and rectified for the batteries of automobiles. Energy may be taken from the system for electric stoves or cooking apparatus or for warming. It may be also consumed in heating metal, as in electric welding, or in electric purposes. It may produce ice in refrigerating machines driven by electric motors. The applications of electric motors are already innumerable. The time will come when cooling in summer will not depend on ice delivered at our doorsteps or in our refrigerators. We may turn a switch, setting in motion a small refrigerating apparatus which transfers heat from water to be cooled or frozen to other water to be warmed. A modicum of the electric output may go to the uses of the physician in such indispensables as Roentgen-ray tubes. The dentist also calls for his supply.

In recent years electricity has added to our resources many remarkable and valuable products. Among those are carbide of calcium and from it acetylene gas. The electric furnace gives us such ideal grinding materials as carborundum and alundum. By way of contrast to these, it furnishes artificial graphite for lubrication. It furnishes supplies of such elements as silicon and boron, until recently practically unknown even in the laboratories.

Aluminum, magnesium, sodium, calcium are made commercial products by electrolytic methods of production. Through cheap aluminum we have thermite for welding. We also obtain by it pure metals, such as manganese for forming alloys. Lastly, in late years large electric furnaces enable us to secure high temperature for refining great baths of steel, or producing special high grades from crude material. Electrochemical baths refine our copper and yield such products as chlorine, caustic soda, and bleaching powder, as well as the chlorates. Special electric furnaces give us phosphorus for matches, and others, carbon bisulphide. Within a few years past water-power has been employed, as in Norway, in the commercial production of nitrates, by combining the nitrogen and the oxygen gases of the air in huge, specially-formed electric arcs. These nitrates add to our agricultural resources, on which the food supply and, as a consequence, the population of the world depend.

It would be out of place here to recount the numerous improvements which our electrical machines are constantly undergoing. There are many minor advances, improvements in design, in disposition and character of materials, in manufacturing methods, and the thousands of things that contribute to an art so varied and extensive in its field.

Very recently I came across by accident an article on the "Future of Electricity" which I had written for a magazine now defunct. It was published in 1892—just twenty years ago. The forecast therein given has not only in the main proven true, but in not a few instances has been many times exceeded. Wireless telegraphy, then predicted as a possibility between ship and shore for moderate distances, in spite of storm and fog, has crossed the Atlantic. Telephony, alluded to as feasible over hundreds of miles, has thousands to its credit. Long-distance transmission of electric energy has very greatly exceeded our most sanguine anticipations of twenty years ago. Our dynamos are of far greater capacity than any of us could have imagined possible. In all directions our expectations have been far exceeded, and unexpected new discoveries have opened up a range of newer applications.

We must leave the future to tell its own story, lest we repeat the same underestimation.

Fusion of Pure Quartz. BILLON-DAGUERRE. (*Comptes Rendus,* cliv, 506.)—The powdered quartz in a carbon crucible is first heated by the electric arc till softened, at about 1800° C., then further heated by the oxy-hydrogen flame and drawn out into rods, from which tubes, crucibles, basins, and other articles are produced. Blocks of quartz for optical purposes are manufactured by casting and compression.

Copper Amalgam. A. GUNTZ and DE GREIFT. (*Comptes Rendus,* cliv, 357.)—Copper amalgam prepared in the cold (*e.g.,* by electrolysis with a mercury cathode), and submitted to increasing pressures in chamois leather, loses mercury until a residue of the composition $HgCu$ is left, from which mercury cannot be removed even by a pressure of 6,250 kilos. per sq.cm. Amalgams of this composition prepared in the cold melt at 135° C., and, after cooling again, practically the whole of the mercury can be removed by pressure. Copper amalgams, shortly after being heated above 135° C., possess densities equal to those calculated on the assumption that the two metals are simply mixed; but if the amalgams are prepared in the cold, or if, after heating, they have remained cold for several days, their densities are considerably higher than those calculated. It is concluded that copper amalgams formed in the cold contain a compound, $Hg\,Cu$, dissolved in excess of mercury, which may be removed by pressure in chamois leather. This compound is decomposed at 135° C., and, on cooling again, requires about three days to be re-formed.

EFFICIENCY IN EDUCATION.[1]

BY

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We are living at a time in which the question of securing the highest efficiency in every form of business enterprise has become a dominant one. No man would undertake a business unless he could assure himself at the very outset that every department of it could be conducted both economically and efficiently.

For a man to take such precautions is not only an evidence of good common sense, but the stand is one that must be taken as a matter of self-protection.

There have been times in the progress of almost any kind of business when it was possible to keep it alive, and even prosperous, in spite of the careless and wasteful methods employed; but at the present time, when our excellent systems of communication have brought all parts of our country together and when manufactured products can be quickly delivered to the places where they are needed, however remote, any manufacturer is almost as keen a competitor of another a thousand miles away as though they both lived in the same city.

Space and time have been annihilated, from the business stand-point, and the man who does not meet the standards of economy and efficiency set up by his competitors will be crowded off the course by their inertia of motion or left stranded far in the rear by his own inertia of rest.

Since there is such a demand for high efficiency in the business world it may be well for us to inquire whether there can be efficiency in education, and, if so, how it may be secured.

At the very beginning we are met with fundamental differences in the conditions. In the factory one has to do with inert matter; in the school with individuals whose actions are governed by their own wills. In the factory we deal with a piece of automatic machinery which does the thing for which it was made, or, if it does not and refuses to work at all, it is largely our own fault in allowing it to get out of repair and become useless. In the school we deal with separate personalities, no two of which are alike and no two of which are sure to do the same thing under exactly the same conditions; while, if the results obtained are not what we want, we are limited to the giving of advice, which is accepted or not according to the mood or fancy of the one who receives it.

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[1] Address delivered at the meeting of the Alumni Association of The Franklin Institute, March 23, 1912.

It would seem, then, by this comparison of the material with which we have to deal, that the problem becomes a much more difficult one when we bring it into the field of education.

When a man designs a piece of automatic machinery he must, in order to be at all successful, have very definitely in mind the purpose for which the machine is being designed: what it is that the machine is to do. To take any other course would stamp the attempt with failure from the start.

To secure efficiency in education, should there not be the same clear-cut, definite knowledge of the result to be obtained? There is in both cases a groundwork of that which is fundamental. In the case of the designer it is his knowledge of the physical qualities of the materials to be used. He must know what the limit of elasticity is, of the material that he proposes to use in every part. He must know whether it will be able to stand the strains that will be put upon it in the work that it has to do. He must know whether there is a choice in this material, and he must make choice of the very best, or the next man who takes up the problem and who can profit by what he has done will so far surpass him in his design that the work shall be a failure through the very competition that it invited, by not being the best machine that could be made. Not only must the designer have this fundamental information, but this fundamental strength, this fundamental elasticity, this fundamental adaptability must have been put into the material by the maker, or the machine will be a failure through his lack of this fundamental knowledge.

The same thing obtains in efficient education. There are, first of all, the fundamentals to be obtained and to be made such a part of the every-day life of a child that they seem to him things that have always been known.

At the very foundation of these fundamentals I would place the ability to think straight. Perhaps you think that I am beginning at the wrong end and that the ability to think straight is the aim and end of education and cannot be had at its beginning. Well, there may be some reasons for your opinion, but I really believe that in order to secure efficiency in education it must be founded upon the ability to think straight, to have the moral sense of what is right and what is wrong, and, moreover, I believe that this ability is common to most men and women.

To the man who does not think straight or who will not, an education brings at most the ability to succeed in things in which it would be better if he should fail. There is another phase of thinking straight, and that is to have one's thoughts clear and well defined. This, too, seems to me to be one of the fundamentals in education.

If we are to have any hope whatever of being of service to those about us, or of being influential among them, we must be able to present our opinions to them in a clear and forceful manner, and this we cannot do unless we are able to think them out clearly to ourselves. It is a pleasure to listen to a man who has a definite purpose in his mind and also has the ability to express that purpose in fitting words, and so I would include, as another fundamentally important thing, an ability to use one's native tongue forcefully.

Too frequently, none of the things that I have mentioned are considered as a necessary part of an education at all. In addition to the ability to understand and use the English language, there is one other department of knowledge that lies at the very foundation of daily life, and that is mathematics. Now, do not think of the kind of mathematics that delights the mathematician, for what I mean is the fundamentals—that is, the elementary mathematics, such as arithmetic, algebra, and geometry. If we consider for a moment that the great discoveries of Nature were most of them made with just these branches of mathematics applied to the questions in hand, possibly adding trigonometry for the use of the astronomer, we shall see that the essentials are elementary.

No one can live in our times, surrounded as we are by the most striking applications of science, without feeling that a study of the natural sciences is required in order to consider that we may be entitled to the name of educated people. Here, again, the fundamentals are of the greatest importance. Take, for example, electricity, which has so general an application in lighting, heating, and furnishing us a means of transportation. As a matter of fact, the essentials are few. It is in the applications that there is so great a divergence. Let a man be thoroughly grounded in the elementary principles of magnetism and electricity: it is a simple matter of diligent application of these principles that solves the most intricate problems to be met.

When we calculate the efficiency of an electric generator, for example, we find that it is the ratio of the power output to the power output plus the *losses*. How are these losses made up? Why, there is the loss in the shunt field, and this we expect and are willing to allow, because if there were no shunt field there would be no lines of magnetic force for the armature wires to cut and there would be no voltage generated for delivery at the brushes. Then there is the armature loss, and this we expect, for there must be wires to cut the lines of force, and they all have some resistance; hence there is a heat loss in the armature that increases as the current increases. Then there are the stray losses—those heart-breaking losses that the designer tries to cut down and generally fails: losses that have no compensation; that have no redeeming feature; that are only detrimental to the machine, and that cut down its efficiency ten per cent. How are these losses made up? Why, there is the friction between the shaft and bearings, between the brushes and commutator, between the rotating armature and the air. There is the time-lag or hysteresis loss, and there is the eddy current loss which is due to currents set up by the cutting of the magnetic lines by the armature core or the pole pieces, and which only serve to heat up the machine and increase its resistance. Now, how does this apply to education? What I would say is that if we wish to increase efficiency in education we must cut down the losses. Perhaps there are some of them that are really so connected with the system or method that they cannot be avoided. But there are certain others—the stray losses—that are wholly harmful, and these should be eliminated. The friction losses between teacher and taught should disappear. The system should be so changed that friction between both teacher and taught and the system should not be possible. And, greatest of all, the eddy currents, those vampires that destroy uselessly, caused by inattention, lack of interest, lack of enthusiasm, should be themselves destroyed.

To insure efficiency in education there must be a greater saving in another great loss, and that is in the loss of time. This requires that one shall know without question what it is that he wants to inform himself on, and not flounder along helplessly for months or years with no definite goal in view. You who have had the opportunity of taking the courses that the Franklin Institute offers have had the advantage of knowing definitely what it was you wanted to study. You have had the opportunity placed before you of applying yourself directly to the problem in hand, and if you have taken advantage of these opportunities you have the consciousness that the education so secured has brought with it something that has been of real and lasting value. I believe we should never look upon our education as a thing of the past. I greatly admire the point of view of the centenarian who had completed his hundredth year in this year 1912 who went to a shoemaker to have a pair of shoes repaired and was very insistent that they should be made strong enough to last a long time. The shoemaker said to him, "Why, you are a hundred years old, and still you seem to be as anxious that these shoes shall last as though you were to live another hundred years." "Well," said the old man, "perhaps I shall. I am a great deal stronger than I was when I started out in 1812." That is the kind of optimism that I like.

Refractories. F. A. J. FITZGERALD: (*Med. and Chem. Eng.*, x, 129.)—*Alundum* (*fused alumina*).—Pyrometer tubes of alundum are now made; they are more refractory and have a higher heat conductivity than porcelain or fire-clay tubes. As a roof for electric steel furnaces alundum bricks resist the high temperature, but show a tendency to break off in layers, owing to the action of lime vapor arising from the basic slag.

Maganese Steel. ANON. (*Amer. Mach.*, xxxvi, 9, 348.)—An ingot of manganese steel is as brittle as glass, but when re-heated to a temperature of 1000° C. or higher, and suddenly chilled by plunging into water, it becomes as ductile as soft carbon steel or wrought iron, and has three times their tensile strength. Manganese steel cannot be forged except with great difficulty, and, as there is no method known of softening it, cannot be machined for practical purposes. Articles made of manganese steel are therefore cast, re-heated, and chilled.

The Atomic Weight of Calcium and Molecular Weight of Lime. OECHSNER DE CONINCK. (*Mon. Sci.*, ii, 843, 208.)—The molecular weight of lime was determined from calcium formiate, made from very pure lime and crystallizable formic acid. It was first gently calcined, then at a high temperature. In one experiment Iceland spar was dissolved in dilute hydrochloric acid, the solution treated with ammonia and precipitated by ammonium oxalate. Four determinations were made with formiate and the last with oxalate. The result gave the figure 56.02 for lime and 40.03 for calcium, which is closely approximate to the figure 40.07 adopted by the international commission on atomic weights.

Sodium Perborate as a Bleach. ANON. (*Revue Sci.*, xiii, 407.)—Sodium perborate, $NaBO_3$, under the name of Persil is now used for bleaching linen. A solution of sodium perborate heated to 60° C. gives sodium metaborate and oxygenated water. For bleaching cotton, it is first boiled with alkasil (sodium monosilicate), and then in a bath containing five per cent. of perborate. The temperature should be below 25° C. for bleaching flax, hemp, jute, and ramie; hypochlorites, sodium peroxide, and perborate are used concurrently. The last gives a very decided white color, after several hours' steeping at 70° to 80° C., and maceration. After the use of hypochlorites the perborates act as an antichlor. Oxygenated water is used to bleach straw, and is obtained by the use of sodium peroxide or perborate in a solution acidified with oxalic acid. A one per cent. solution of blankit (sodium hydrosulphite) is also used. Plants, used as ornaments, are sterilized and decolorized by a solution of perborate. Wool is bleached by perborate, preferably in water acidified with lactic acid. To bleach silk, it is first washed in soapy water mixed with benzine, which emulsifies the fatty matters, particularly sericine; then 2 to 3 kilograms of perborate are added to a bath of 1,000 litres, and 10 kilograms of cocoanut-oil soap. Chinese hair can be decolorized to white with baths of soap, to which alkasil and perborate are added, finishing by an immersion in ammoniacal oxygenated water.

NOTES FROM THE BUREAU OF STANDARDS.

THE MELTING POINTS OF FIRE BRICKS.[1]

BY

C. W. Kanolt,
Assistant Physicist.

We are accustomed to thinking of a melting point as a temperature at which a substance changes from a rigid to a fluid condition, but a melting point can be precisely and rationally defined only as the temperature at which a crystalline or anisotropic phase and an amorphous or isotropic phase of the same composition can exist in contact in equilibrium. While this definition is satisfactory for pure substances, so complex a mixture as an ordinary fire brick usually has no single definite melting point according to this definition, since several anisotropic phases may be present, all differing in composition from the isotropic phase produced by fusion. We can then only select the temperature at which the transition from a rigid to a fluid state seems most distinct, and can call this the melting point only by apology. In the case of fire bricks, the transition temperatures so found are, fortunately, sufficiently distinct. I have taken as the melting point the lowest temperature at which a small piece of the brick could be distinctly seen to flow.

The experiments were conducted in an Arsem graphite resistance vacuum furnace. The samples were usually inclosed in a refractory tube made of a mixture of kaolin and alumina in the proportions to form sillimanite, to protect them from the small amount of reducing gas in the furnace, although the action of this gas was slight. The samples were observed through a glass window in the top of the furnace.

The temperatures were determined by means of a Morse optical pyrometer of the Holborn-Kurlbaum type, which was sighted vertically downward through the glass window. The carbon-filament pyrometer lamp was calibrated by two methods. In the first calibration it was sighted into a platinum resistance furnace in which black-body conditions were obtained, and the temperature of which was measured by platinum platinum-rhodium thermocouples. These thermocouples had been calibrated against the freezing points of pure metals. In the second calibration the lamp was calibrated against the freezing points of metals directly, without the intermediation of thermocouples. The metals used were copper, silver, and the copper-silver eutectic, which freeze at 1083°, 961°, and 779°, respectively. The metals were melted in the vacuum furnace in graphite crucibles, the pyrometer being sighted into a thin-walled graphite tube inserted in the metal. The pyrometer readings corresponding to the freezing points were determined by means of cooling curves. With silver and copper, heating curves were also obtained.

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[1] Abstract of forthcoming Technologic Paper to be issued shortly.

As the melting points to be measured were above the working limit of the pyrometer lamp, an absorption glass was interposed between the pyrometer and the furnace.

The true temperatures were then found from the apparent temperatures measured through the glass, by means of the equation

$$\frac{1}{T_2} - \frac{1}{T_1} = A,$$

where T_1 is the absolute temperature of the furnace, T_2 is the apparent temperature observed through the glass, and A is a constant. The value of A was determined by calibrations at various temperatures. A small correction was also applied for the absorption and reflection of the glass window of the furnace.

The samples, which were from one to two centimetres in diameter, were heated at the rate of about ten degrees per minute when near the melting point. It was found that in the case of certain bricks made of heterogeneous material of relatively low melting point the melting points were slightly higher after six hours' heating to 1550°, apparently as the result of the gradual running together of dissimilar particles to form a mixture having a higher melting point than the most fusible of the original materials.

The results are summarized in the following table:

Material.	Number of Samples.	Melting point, Centigrade.
Fire clay brick	41	1555° to 1725° mean 1649°
Bauxite brick	8	1565° to 1785°
Silica brick	3	1700° to 1705°
Chromite brick	1	2050°
Magnesia brick	1	2165°
Kaolin	3	1735° to 1740°
Bauxite	1	1820°
Bauxite clay	1	1795°
Chromite	1	2180°
Pure alumina		2010°
Pure silica		1750°

The value 1750° given for silica is not the true melting point, but represents approximately the temperature at which the silica flows distinctly. It was found that silicon carbide does not melt below 2700°; it becomes unstable at much lower temperatures.

MELTING POINTS OF CHEMICAL ELEMENTS.[1]

The values of the melting points used by the Bureau of Standards as standard temperatures for the calibration of thermometers and pyrometers are indicated in capitals. The other values have been assigned after a careful survey of all the available data.

As nearly as may be, all values, in particular the standard points, have been reduced to a common scale, the thermodynamic scale. For high temperatures, and for use with optical pyrometers, this scale is satisfied very exactly by taking $c_2 = 14500$ in the formula for Wien's law connecting I, monochromatic luminous intensity of wave length λ, and T, absolute temperature: $\log I/I_1 = c_2 \lambda \log e \ (1/T_1 - 1/T)$. For all purposes, except the most accurate investigations, the thermodynamic scale is identical with any of the gas scales.

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[1] From Circular No. 35, June 15, 1912.

MELTING POINTS OF CHEMICAL ELEMENTS.

Element.	F.	C.	Element.	F.	C.	Element.	F.	C.
Helium	< −456	< −271	CADMIUM	609.6	320.9	Cobalt	2714	1490
Hydrogen	−434	−259	LEAD	621.1	327.4	Chromium	2750	1510
Neon	−423	−253?	ZINC	786.9	419.4	IRON	2768	1520
Fluorine	−369	−223	Tellurium	846	452	PALLADIUM	2820	1549
Oxygen	−360	−218	ANTIMONY	1166	630.0	Zirconium	3100	1700?
Nitrogen	−346	−210	Cerium	1184	640	Thorium	> 3090 < Pt.	> 1700 < Pt.
Argon	−306	−188	Magnesium	1204	651	Vanadium	3150	1730?
Krypton	−272	−169	ALUMINUM	1217.7	658.7	PLATINUM	3191	1755
Xenon	−220	−140	Calcium	1490	810	Beryllium	> 3270	> 1800?
Chlorine	−150.5	−101.5	Lanthanum	1490	810?	Ytterbium	....	?
MERCURY	− 37.7	− 38.7	Strontium	....	> Ca < Ba?	Titanium	3450	1900?
Bromine	+ 18.9	− 7.3	Neodymium	1544	840?	Rhodium	3525	1940
Cæsium	79	26	Arsenic	1560	850?	Ruthenium	> 3550	> 1950
Gallium	86	30	Barium	1560	850	Columbium (Niobium)	4000	2200?
Rubidium	100	38	Praseodymium	1725	940?	Boron	4000–4500	2200–2500
Phosphorus	111.4	44	Germanium	1756	958	Iridium	4170	2300?
Potassium	144	62.3	SILVER	1761	960.5	Uranium	....	?
Sodium	207.5	97.5	Glucinum	....	> Ag	Molybdenum	4500	2500?
Iodine	236.5	113.5	Radium	....	?	Osmium	4900	2700?
Sulphur	S_I 235.0 S_{II} 246.6 S_{III} 224.2	112.8 119.2 106.8	GOLD	1945.5	1063.0	Tantalum	5160	2850
Indium	311	155	COPPER	1981.5	1083.0	TUNGSTEN	5430	3000
Lithium	367	186	Manganese	2237	1225	Carbon	> 6500 for p = 1 At.	> 3600 for p = 1 At.
Selenium	422–428	217–220	Yttrium	....	?			
TIN	449.4	231.9	Samarium	2370–2550	1300–1400			
Bismuth	520	271	Scandium	....	?			
Thallium	576	302	Silicon	2588	1420			
			NICKEL	2646	1452			

THE RELATION OF THE HORSEPOWER TO THE KILOWATT.[1]

THERE was, before 1911, no precise definition of the horsepower that was generally accepted and authoritative, and different equivalents of this unit in watts are given by various books. The most frequently used equivalent in watts, both in the United States and England, has been the round number, 746 watts; and in 1911 the American Institute of Electrical Engineers adopted this as the exact value of the horsepower. It is obviously desirable that a unit of power should not vary from place to place, and the horsepower thus defined as a fixed number of watts does indeed represent the same rate of work at all places. Inasmuch as the "pound" weight, as a unit of force, varies in value as *g* the acceleration of gravity varies, the number of foot-pounds per second in a horsepower accordingly varies with the latitude and altitude. It is equal to 550 foot-pounds per second at 50° latitude and sea level, approximately the location of London, where the original experiments were made by James Watt to determine the magnitude of the horse-power.

The "continental horsepower," which is used on the continent of Europe, differs from the English and American horsepower by more than 1 per cent., its usual equivalent in watts being 736. This difference is historically due to the confusion existing in weights and measures about a hundred years ago. After the metric system had come into use in Europe, the various values of the horsepower in terms of local feet and pounds were reduced to metric units and were rounded off to 75 kilogram-metres per second, although the original English value was equivalent to 76.041 kilogram-metres per second. Since a unit of power should represent the same rate of work at all places, the "continental horsepower" is best defined as 736 watts; this is equivalent to 75 kilogram-metres per second at latitude 52° 30′, or Berlin. The circular gives tables showing the variation with latitude and altitude of the number of foot-pounds per second and of kilogram-metres per second in the two different horsepowers.

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[1] Abstract, Circular of the Bureau of Standards, No. 34; June 1, 1912.

These values, 746 and 736 watts, were adopted as early as 1873 by a committee of the British Association for the Advancement of Science. The value, 0.746 kilowatt, will be used in future publications of the Bureau of Standards as the exact equivalent of the English and American horsepower. It is recognized, however, that modern engineering practice is constantly tending away from the horsepower and toward the kilowatt. The Bureau of Standards and the Standards Committee of the American Institute of Electrical Engineers recommend the kilowatt for use generally instead of the horsepower as the unit of power.

Fallacies in the Theory of the Organic Origin of Petroleums. EUGENE COSTE. (*Mining Sci.*, lxiv, 493.)—Two simple patent geological facts are efficient to disprove and condemn all theories of the organic origin of petroleums: (1) The remains of the soft organic tissues of animals were never entombed in the sedimentary rocks, and (2) the vegetable organic remains were always transformed into coal. The production of CH_4 from decomposing vegetation occurs during the transformation of such material into peat, carbonaceous matter, and coal rather than into petroleum. Everywhere there is a lack of connection between coal beds and petroleum deposits. The analogy between the CH_4 of the coal and of the petroleum is only one of chemical composition, indicating simply that CH_4 can be formed in two or more different ways. The rapid and complete disappearance of all dead animal tissues is well known, while the formation of strata is such a slow process that even the hard parts of animal organisms are often much destroyed before their final entombment. The fossiliferous beds of all ages are entirely barren of petroleum. The abundant production of hydrocarbon gas in volcanic phenomena cannot be disputed. These phenomena manifested along great tectonic disturbances of the earth's crust lead to the belief that fissures caused by dynamic disturbances of the crust permit the escape of vapors and gases, which are trapped in porous portions of the sedimentary strata to form oil and gas deposits. Oil pools are always found grouped along fissured zones of disturbances, and never extend far from the fractures which formed the channels of hydrocarbon emanations from the interior. The same quality of oil may be found in all kinds of strata, as along the Appalachian belt. As much as 0.2 per cent. carbon has been shown to exist in massive crystalline rocks, which is twenty times as much carbon as may be found in the atmosphere; showing that the source of carbon is far from residing in the organic kingdom.

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LIBRARY NOTES.

Purchases.

Foerster, M.—Taschenbuch fur Bauingenieure. 1911.
Burgess, G. K., and H. Le Chatelier.—The Measurement of High Temperatures. 1912.
Timbie, W. H.—Elements of Electricity for Technical Students. 1911.
Fuller, G. W.—Sewage Disposal. 1912.
Townsend, F.—Short Course in Alternating-current Testing. 1904.
Haldane, J. S.—Methods of Air Analysis. 1912.
Gifford, B. T.—Central Station Heating. 1912.
Dartmouth College.—Addresses and Discussions at the Conference on Scientific Management, held October 12, 13, 14, 1911.
Thorpe, E.—Dictionary of Applied Chemistry. Vol. 2. 1912.
Dichmann, Carl.—Basic Open-hearth Steel Process. 1911.
McMeen, S. G., and K. B. Miller.—Telephony. 1912.
Gilbert, G. H.; L. I. Wightman and W. L. Saunders.—The Subways and Tunnels of New York. 1912.
Foster, H. A.—Engineering Valuation of Public Utilities and Factories. 1912.
Floy, H.—Valuation of Public Utility Properties. 1912.
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Taylor, F. W., and S. E. Thompson.—Concrete Costs. 1912.
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Gifts.

E. Keeler Company, Water Tube Boilers. Williamsport, 1912. (From the company.)

Leland Stanford Junior University, 8th Annual Report of the President, for the year ending July 31, 1911. Stanford University, 1911. (From the University.)

Bureau of Soils, Fertilizer Resources of the United States, December 18, 1911. Washington, 1912. (From the Department of Agriculture.)

American Institute of Mining Engineers, Transactions, vol. 42, 1911. New York, 1912. (From the Institute).

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George Washington University, Catalogue, June, 1912. Washington, 1912. (From the University.)

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Board of Trade (Labor Department), 15th Abstract of Labor Statistics. London, 1912. (From the Department.)

Ontario Department of Agriculture, 37th Annual Report, 1911. Toronto, 1912. (From the Department.)

Commissioner of Patents, Annual Report, 1911. Washington, 1912. (From the Commissioner.)

Pennsylvania Topographic and Geologic Survey Commission, Report No. 5. Harrisburg, 1911. (From Mr. E. V. D'Invilliers.)

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American Society of Heating and Ventilating Engineers, Transactions, vol. 16. New York City, 1910. (From the Society.)

Stanford University, Bulletin 64, Register, 1911–1912. Stanford, 1912. (From the University.)

Leland Stanford Junior University, Catalogue de tous les livres de feu M. Chapelain. Stanford University, 1912. (From the University.)

PUBLICATIONS RECEIVED.

Methods of Organic Analysis. By Henry C. Sherman, Ph.D., Professor of Food Chemistry in Columbia University. Second edition, rewritten and enlarged. 407 pages, illustrations, 8vo. New York: The Macmillan Co., 1912. Price, in cloth, $2.40 net.

Chemical Arithmetic and Calculation of Furnace Charges. By Regis Chauvenet, A.M., B.S., LL.D. 302 pages, 8vo. Philadelphia: J. B. Lippincott Company, 1912. Price, in cloth, $4 net.

Pennsylvania Topographic and Geologic Survey. Report No. 5. Preliminary Report on the talc and serpentine of Northampton county and the Portland cement materials of the Lehigh district. By Frederick B. Peck. 65 pages, plates, maps, 8vo. Harrisburg State Printer, 1911.

To Establish an Independent Health Service. Speech of Hon. John D. Works, of California, in the Senate of the United States, Monday and Tuesday, April 29 and 30, 1912. 78 pages, 8vo. Washington: Government Printing Office, 1912.

Duties on Sugar. Report of Senate Committee on Finance, to accompany H. R. 21213. May 17, 1912. 16 pages, 8vo. Washington: Government Printing Office, 1912.

Uber Elektronen, Relativitätsprinzip und äther von L. Zehnder. Sonder-Abdruck aus den Verhandlungen der deutschen Physikalischen Gesellschaft. 11 pages, 8vo. Braunschweig: F. Vieweg und Sohn, 1912.

Uber die Geschichte der Erdantennen, zur abwehr der angriffe des Herrn Kiebitz von L. Zehnder. Sonder-Abdruck aus den Verhandlungen der deutschen Physikalischen Gesellschaft. 6 pages, illustrations, 8vo. Braunschweig: F. Vieweg & Sohn, 1912.

Zur Priorität der Erdantennen von L. Zehnder und F. Kiebitz. Sonder-Abdruck aus den Verhandlungen der deutschen Physikalischen Gesellschaft. 1 page, 8vo. Braunschweig: F. Vieweg & Sohn, 1912.

BOOK NOTICE.

COLLEGE MATHEMATICS NOTEBOOK. By Robert E. Moritz, Ph.D., Professor of Mathematics in the University of Washington. 100 pages, 8 x 10½ inches. Published by Ginn & Co., New York. Price, $1.

This book consists of a "Biflex Binder" loose-leaf notebook with filler, including thirteen printed pages of formulas from algebra, geometry, trigonometry, calculus, etc., mechanics, thermodynamics and electricity and magnetism; four pages of mathematical tables; five pages of logarithmic-ruled paper, and five pages ruled for polar coördinates.

The formulas and tables are well selected and arranged, and the notebook should be of service in the lecture-room or laboratory.

CURRENT TOPICS

Lamp Characteristics. M. TAPPLEY. (*Elec. Rev. West. Elect.*, lix, 528.)—Gas mantles have a working life of 350 hours, carbon filament lamps have 800 to 1,000 hours, and metal filament lamps have 1,200 to 2,000 hours. Gas mantles fall to 80 per cent. candle-power in about 100 hours; carbon and flaming arc lamps do not suffer decadence in candle-power. Open arcs give only 10 to 15 burning hours. The Cooper-Hewitt mercury arc lamp falls to 75 per cent. candle-power in 1,000 hours, owing to a gray film deposit inside the tube, although the quartz type has a guaranteed life of 1,000 hours without appreciable deterioration. The Moore lamp does not blacken appreciably. Tungsten lamps are the least susceptible to voltage fluctuation of all incandescent lamps. Arc lamps do not require so close a regulation, but excessive pressure must be avoided, as the automatic feeding coils give long, unstable, and inefficient arcs. The power factor of filament lamps is practically 100 per cent.; that of arc lamps is 80 to 90 per cent. and the Moore tube is 90 per cent.

Paper Pulp from Eucalyptus. ANON. (*Paper Making*, xxx, 376.)—Samples of pulp of excellent quality have been prepared from the eucalyptus (blue gum), which has been planted over large areas in Southern California. The pulp is strong, clean, and slightly reddish, owing to the action of the alkali. Experiments with this wood as a raw material for paper pulp leave no doubt as to its suitability for the purpose. A sufficient growth of blue gum may be obtained in from four to six years; the stump yields a further good growth three years after the first cutting.

Helium Tubes as Light Standards. P. G. NUTTING. (*Washington Acad. Sci. Journ.*, 1, 221.)—Capillary tubes of about 2 mm. bore containing helium gas have shown useful characteristics as standards of light. The tubes are subjected to a high-tension discharge, the standard current being 25 milliamperes; a consumption of 3.8 watts per candle-power is then obtained. The light is furnished mainly by six prominent spectrum lines. These all increase in intensity uniformly with increasing current, and the connection is approximately linear. Neither voltage nor frequency affects the light appreciably, and the gas density has little effect between the limits of 3 to 8 mm. pressure. A test of the reproducibility of candle-power was made on forty tubes. The average deviation was 1.15 per cent., the maximum 3 per cent.

Results of Experiments with a Water-Tube Boiler with Special Reference to Superheating. HAROLD E. YARROW. (The Fifty-third Session of the Institution of Naval Architects, March 28, 1912.)—The object of this paper is to show the advantages of superheating, in marine engineering, when using a water-tube boiler.

The objections hitherto raised to superheating for marine work have been:

(1) Owing to the dryness of the steam, oil for the internal lubrication in reciprocating engines becomes a necessity, and the oil, finding its way into the boiler, leads to trouble.

(2) The probability of burning the superheater when the passage of the steam through it is suddenly reduced or stopped.

By the introduction of turbines the difficulty of lubrication does not occur, and with regard to burning the superheater tubes, the arrangement adopted avoided this risk.

The boiler experimented on was of the Yarrow type, and oil fuel only was used, hence it was possible to maintain steady and uniform working conditions.

During the experiments careful records were taken of the oil consumed, the water evaporated, steam pressure, temperature of the superheated steam, and the temperature of the gases at various points during their passage past the boiler tubes.

On the left-hand side of the boiler was the superheater, and on this side of the boiler there were fewer rows of generator tubes than on the other side, it being thought desirable that the total heating surface and the resistance to the gases on both sides of the boiler should be approximately the same. The total heating surface of the boiler was 6,700 square feet, of which 1,265 square feet consisted of superheating surface; the total heating surface of the superheater side of the boiler was 3,453 square feet, and on the other side 3,247 square feet. The superheater consisted of a number of "U" tubes expanded into two longitudinal collectors, small doors being fitted so that access could be obtained to the tubes when required. A damper was fitted in the up-take on the same side. When this damper was closed the whole of the gases were deflected towards the opposite side of the boiler, and no heated gases passed the superheater, so that if the main engines were suddenly eased or stopped, or when raising steam, the superheater might be shut off, so as to prevent the tubes being damaged, or the steam being superheated to an excessive extent, owing to there not being sufficient circulation of steam. In this way one objection to the introduction of superheating for marine installations was overcome.

In order to carefully measure the temperature of the superheated steam and of the gases, a complete installation of thermometers and pyrometers was fitted to the boiler.

With the damper open, at the maximum rate of evaporation, namely, when burning 1,237 pounds of oil per square foot of heating surface per hour, the degree of superheat was 93°. Tests, burning oil fuel at a rate of consumption considerably greater than has hitherto been the custom, to ascertain if the boiler would, under such conditions, show any defects, were carried out for purposes of information. Nearly 2 pounds of oil per square foot of heating surface per hour were consumed—if the heating surface on the superheater side of the boiler be disregarded. Thus, the surface on the opposite side of the superheater was subject to the heating effects of all the gases plus half the radiation. Every part of the boiler withstood the severe test, and trials burning this quantity of fuel were made on several occasions.

The results of other experiments indicated that in a properly-designed boiler of the type dealt with it was possible to burn, without injury to the boiler, 2 pounds of oil per square foot of heating surface per hour.

Since these experiments were carried out official trials have taken place with one of the British Admiralty destroyers, H. M. S. Archer, in which boilers fitted with superheaters were provided. The result of these trials showed that the gain expected was fully realized, and on the full-speed trial the degree of superheat at the turbines was 94°, the S. H. P. developed was slightly over 18,500, which compared with about 17,000, the S. H. P. expected had the boilers been of the usual type. The mean speed for eight hours was 30.3 knots, the contract speed being 28 knots.

One outcome of the experiments was the proposition to have in some cases an additional damper on the opposite side to the superheater, the two dampers being arranged so that either can be open, or both open, but under no condition can both be closed. This enables the superheater side of the boiler to be used to a greater or less extent, as desired. When cruising at a slow speed this arrangement may possibly lead to a more economical result than if both sides of the boiler are equally free for the passage of the hot gases.

Judging by the best practice in land installations, 100° F. superheat is by no means the limit that can be adopted with advantage. It is reasonable to suppose that the requisite condition to be desired is that the steam should remain in gaseous form so far as possible during its passage through the turbine, because any condensation that takes place must diminish the energy given out by the steam to the blades of the turbine; also, if the steam remains in gaseous form, the steam friction is reduced.

The Utilization of Atmospheric Nitrogen.—The importance of nitrogenous compounds to the agricultural and industrial interests of Europe and America has promoted the Bureau of Manufactures to issue a monograph on the subject of utilizing atmospheric nitrogen in the production of such compounds.

The nitrogen problem, one of the most pressing of the twentieth century, is unique from the fact that the material is unlimited. The atmospheric nitrogen above one square mile of land, amounting to about 22,000,000,000 tons, is equivalent to what the world would require in the next fifty years at the present rate of consumption. The problem is to utilize this nitrogen economically, and thus free the world from its dependence on the nitrates of Chile, which are not particularly extensive and are likely to be exhausted at a comparatively early date.

Remarkable results have been obtained in Norway by means of electric furnaces in which atmospheric nitrogen is oxidized to the form of nitric oxide, which is caused in making calcium nitrate, or Norway saltpetre. This Norwegian product is already an important rival of Chile saltpetre, but as the success of the process depends upon a very cheap supply of electricity it will probably not be used to any great extent in the United States until the furnaces have been made more efficient.

Cyanamide, another nitrogenous fertilizer of growing importance, is being manufactured in America, and the industry should prove successful, as the production in this country of the calcium carbide required by the process is second only to that of Norway.

The monograph describes in detail the results obtained by the leading European chemists in their efforts to increase the supply of nitrogenous compounds, and the commercial as well as the technical aspects of the new industry are dealt with at length. The author, Thomas H. Norton, Consul at Chemnitz, Germany, on detail as commercial agent of the Department of Commerce and Labor, states, in conclusion, that the achievements of applied chemistry make it possible for American industry and agriculture to face with confidence the threatened exhaustion of the nitrate deposits of Chile.

The Growth of Plants Aided by Electricity. F. L. COOKE. (*Elect. Rev. West. Elec.,* lix, 975.)—This is an account of experiments made by *Glaede* on the stimulation of plants by high-tension electric currents. In hot-house beds a single galvanized iron wire was embedded in the soil. A network of wires forming about a 12-inch mesh was placed about four feet above, insulated from the supports. Short brass chains were suspended at frequent intervals along this network. A current of 600 cycles, at 250,000 volts, was applied to the two sets of conductors, and thus an electric field was formed in the space occupied by the flower beds. Chrysanthemums grew much more rapidly, were much stronger and hardier, and showed twice as many blooms per plant. Fungus growths in the soil were killed. Roses and carnations gave four times the ordinary yield, and a marked absence of stem-rot was noticed. With a similar arrangement in the open air garden, radishes were grown three inches in diameter, which retained their flavor and were neither pulpy nor stringy. Tomatoes and corn grew to unusual size, at the same time keeping their uniformity of shape. Musk-melons developed rapidly and yielded an enormous crop. Melons and beets were noticeably sweeter.

Pulverization of Metals by the Oscillating Discharge. J. de Kowalski and E. Banasinsky. (*Arch. des Sci.,* xxxii, 468.)—It has been shown that metallic electrodes employed in the production of an oscillating discharge of a condenser are pulverized. The metals may be arranged, in descending order of degree of pulverization, as follows: gold, platinum, zinc, iron, copper, silver, aluminum. It is now shown that the effect increases with the explosive distance whatever metal is used, and that it diminishes with the capacity, this being more pronounced for large than for small explosive distances.

Electrical Resistivity of Special Steels. O. Boudouard. (*Comptes Rendus,* cliii, 1475.)—The resistance of nickel, manganese, chromium, and tungsten steels was determined by Kelvin's method. Two series of alloys with each metal were made, one containing 0.1 to 0.2 per cent. of carbon, and the other 0.8 to 0.9 per cent. of carbon. The general results were: in carbon steels the resistance increases with the carbon content. With constant nickel, carbon considerably increases the resistance, and the curve passes through a maximum approximately corresponding to the formula $\mathrm{Ni\,Fe_2}$. Carbon appears to have very little effect on the manganese steels, otherwise there appears to be a maximum corresponding to 12 to 13 per cent. manganese. In the chromium series irregularities arise regardless of the carbon content. The resistances of tungsten steels are not affected to any considerable extent by the state of the metal, whether hard, annealed, or ordinary, but the curve appears to pass through a maximum, then through a minimum, and finally increases rapidly. Application of Benedick's formula to the carbon steels gives results in good agreement with the observed figures, but the formula does not apply to special steels except in indicating the specific influence of a metal on the resistance of the steel under consideration.

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THE ELECTRICAL PRECIPITATION OF SUSPENDED MATTER IN GASES.[1]

BY

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THE purpose of the present investigation is to study the electrical properties of gases containing solid and liquid matter in suspension (especially smoke from soft coal), and to ascertain the manner by means of which an electrostatic or an electromagnetic field will cause a separation of the suspended solid and liquid matter from a gas. As the most effective electrical process for removing the suspended matter from gases necessitates the presence of the electrical wind or of the corona form of discharge, a brief description of these two forms of discharge and their probable action upon solid and liquid particles suspended in the gas will be given. The following is the outline of the paper:

1. A review of work upon electrical precipitation.
2. Experimental apparatus.
3. The various types of electrical precipitation.
4. Aggregation. (*a*) The attraction between charged particles. (*b*) The Bjerknes effect.
5. Precipitation and ionization. (*a*) The electrification of

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[1] Communicated by the author.

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dust and sprays. (*b*) Smoke patterns. (*c*) The effect of ionization on the sparking potential in flue gases.

6. The electrical wind and its action upon suspended particles. (*a*) The Cottrell method of precipitation.

7. The corona discharge and its action on particles suspended in a gas. (*a*) Application to the precipitation of cement dust.

8. Precipitation of coal smoke.

9. Summary.

(1) ELECTRICAL PRECIPITATION.

The precipitation of suspended matter from gases by means of electrical discharges was suggested by Hohlfeld [1] in 1824 and by Guitard [2] in 1850. Lodge and Clark [3] and Lodge [4] were the first investigators to go into the problem extensively. Lodge states that the discharge from points kept charged to a high potential by means of an electrostatic machine produced a clearance of the suspended matter in the neighborhood of the points. This clearance seemed to be independent of the nature of the suspended material and of the sign of electrification of the point. Walker [5] patented the above "process for separating and collecting particles of metals or metallic compounds, applicable for condensing fumes from smelting furnaces and for other purposes." According to Walker's arrangement, one electrode of the electrostatic machine was earthed, while the other was connected to an electrode covered with metallic points, against which the fumes made contact. This is the "active" electrode.

Apparatus of the above type was installed in the Dee Bank Lead Works, but on account of the unreliability of the source of electricity—Wimshurst electrostatic machines—the method was apparently a failure. Thwaite [6] took out a patent in 1899 in which a barbed wire is used as the active electrode. In the description this is mentioned as being positively charged.

It is to F. G. Cottrell [7] and his coworkers that we owe the recent commercial development of electrical precipitation. In his 1908 patent he claims the following conditions to be favorable for successful operation: First, the current should be unidirectional, or, at least, the time occupied by its reversal should be large compared with the time of deposition of the individual suspended particles; second, the particles should be charged at or near the electrode about which the brush discharge appears (the "active" electrode); third, the particles should be deposited on a surface from which there is practically no brush or wind discharge (earthed electrode); fourth, the suspended particles in the gas should be subjected to as uniform treatment as possible. High voltage alternating current was made unidirectional by the use of a synchronously-driven rotating commutator. In order to make the brush or glow discharge as great as possible, the active electrode was wound with asbestos threads, strips of mica, etc. The surface of the asbestos is usually moist enough to act as a conductor so that the exposed fibres give point discharges into the gas. Such electrodes Cottrell calls "pubescent." The patent includes claims to the maintenance of the insulation of the pubescent electrodes by means of currents of clean gas and by heating. Howard[8] took out a patent on the use of horizontal plate electrodes for precipitating fumes. Nothing is stated concerning the electrical conditions necessary.

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[1] Kastner, Archiv. Naturl., 2, p. 205, 1824.

[2] *Mechanics' Magazine,* Nov., 1850.

[3] *Nature,* 28, p. 297, 1883.

[4] *J. Soc. Chem. Ind.,* 5, p. 572, 1886.

[5] English patent 11,120, Aug. 9, 1884; U. S. patent 342,548, May 25, 1886.

[6] U. S. patent 617,618, Jan. 10, 1899.

[7] U. S. patents 895,729, Aug. 11, 1908; 945,917, Jan. 11, 1910.

In a patent taken out by Dion[9] the action of the electrical current is that of aggregating the fume particles and then allowing them to settle. It is stated that under the same conditions metallic particles of different kinds are precipitated to a different degree, and this fact is stated as affording a means of separating the various fume materials. Metallic plate electrodes are described, the electrodes being of a composition determined by the kind of fumes to be precipitated. Direct current of apparently low voltage is used to charge the electrodes. A description of the plants that have been planned more or less along the lines indicated in the Cottrell patent will be given in the latter part of this paper.

(2) EXPERIMENTAL APPARATUS.

For the purpose of studying the smoke produced in the burning of soft coal, a small building about 12 by 15 feet was built. This building included a small furnace and an underground pipe, by means of which the smoke could be conveyed to any part of the building. Fig. 1 shows the furnace, 60 cm. high, 60 cm. wide, and 100 cm. long. Below the furnace is an

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[8] U. S. patent 896,111, Aug. 18, 1908.

[9] U. S. patent 925,626, June 22, 1909.

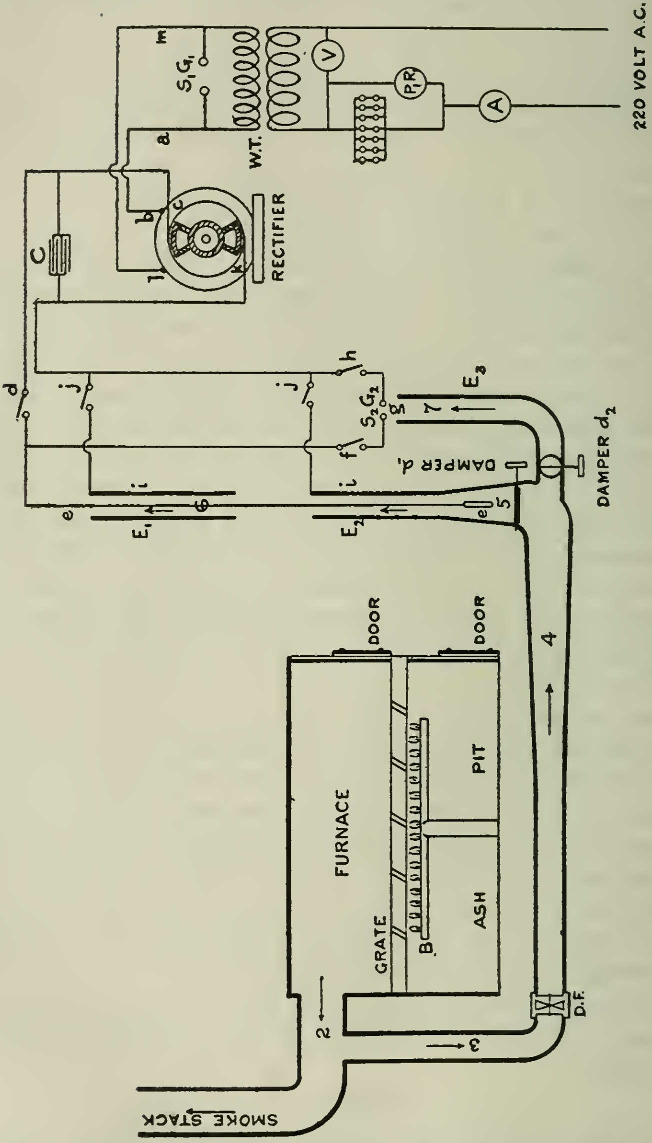

FIG. 1.

ash pit. *B* is a gas (natural gas) burner used for starting the fire. The inside of the furnace is lined with refractory brick, while the outside is covered with ordinary brick.. On account of its construction the furnace proved to be a most efficient smoke producer.

D.F. is a small fan run by an alternating-current motor. When the fan is running, smoke is carried in the paths 2 3 4 5 6 or 2 3 4 7, according as the damper d_1 is open and d_2 is closed or d_1 closed and d_2 open. The draft in a 3-inch pipe could be varied from zero to 0.5 inch of water.

The electrical apparatus used in these experiments has been mostly of the sort to give the various kinds of high-tension discharges. This has included a Wimshurst electrostatic machine, a pneumatic influence machine, a Fessenden wireless induction coil, a Westinghouse instrument transformer, small Blitzen and Marconi transformers, and a high voltage rectifier. The Wimshurst machine, the Fessenden coil, and the Westinghouse transformer were very kindly loaned for the work by Dr. Bishop, of the Physics Department of the University.

The pneumatic influence machine was obtained through Eimer & Amend, of New York. It had cylinders 15 inches in diameter, enclosed in a case 10 inches thick. These machines are made to work under a pressure of about 50 pounds per square inch. The plates are made of a nonoxidizable material, so that the presence of discharge does not result in a breaking down of the insulation. The machine used is stated as giving an 11-inch spark at a pressure of 30 pounds. The Westinghouse transformer is rated to give 60,000 volts, and withstands as much as 80,000 volts. Hague and Olesen[10] give the ratio of transformation as 237. Two Westinghouse potential induction regulators accompanied the transformer so that the voltage on the primary could be varied between 0 and 350. The Blitzen transformer was a small one, weighing about 40 pounds, operating directly on the 110 alternating-current terminals and giving about 15,000 volts.

The rectifier was purchased from the Balaklala Consolidated Copper Smelting Company, of Coram, Calif. It was built for strength, and stood on a heavy cast-iron base. It was started by a direct-current motor, and when in synchronism was run by a 220 three-phase alternating-current motor working on the shaft of the rectifier itself. Through the generosity of Dr. Cottrell we have been loaned one of his rectifiers.

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[10] Dissertation, "Determination of Electrostatic Fields," University of Pittsburgh, 1911.

In the figure *W.T.* is the Westinghouse transformer; S_1 G_1, a protective spark gap; *A,* an alternating-current ammeter; V, a voltmeter; *L,* a bank of lamp resistance; P_1 R_1, a potential regulator that could be connected in the primary circuit, *L* then being cut out; *C* is a condenser, which, however, is seldom used. By the proper switch connections the high-tension current can be made to flow through either of the circuits *a b c d e i j l m* or *a b c d f g h l m.* The former circuit contains an active wire electrode, *e,* suspended in the middle of pipes E_1 and E_2. The part E_1 could be insulated or earthed. One use to which E_1 is applied is that of obtaining a precipitation of particles that are not thrown down in E_2. The pipe E_3 is used to make spark gap measurements.

The spark gap S_2 G_2 can be varied in length and can also be subjected to flue gases of different temperatures, velocities, or smoke content, depending on the condition of the furnace, the speed of the fan *D.F.,* and the pipe dimensions.

A few experiments were made with S_2 G_2 placed in the smokestack, but the arrangement is not represented in the figure.

(3) THE VARIOUS TYPES OF ELECTRICAL PRECIPITATION.

Suspended solid and liquid particles in gases may be acted upon in various ways by an electric field so that some or all of the particles are drawn from the gas to the electrodes. (1) If the particles are conducting, the effect of the electric field is to polarize the particles, inducing a positive charge on one side and a negative charge on the other side. This action of the field probably plays an important rôle in producing aggregates of fine particles that are close to each other. (2) If the suspended particles are non-conductors their dielectric constant will be greater than that of the gas, and in an electric field that is not uniform the particles will move into the more intense part of the field. (3) Gaseous ions may be present in the gas, and some of these will combine with the suspended particles. Such charged particles are the large ions, and these move very slowly in the weaker fields. Large ions are always gaining and losing charges, and this process may aid in aggregating together the smaller particles. (4) The above processes, by means of which suspended particles can be removed from a gas, apply only to cases where the gases move very slowly between the electrodes. When there is intense ionization and an intense electric field, streams of ions will be created between the electrodes. Under these conditions the streams of ions carry the suspended particles in the gas with them to the electrodes, to which they give up their charge. Streams of ions are produced in the various point, brush, and corona discharges. The ions in these cases are probably produced by collision or secondary ionization in the regions where the electric field is the most intense.

The relative importance of the above effects in removing suspended particles from a gas is quite different. Polarization of the particles probably causes the formation of comparatively large aggregates, and these can then be swept out of the gas by the streams of ions flowing through it.

Particles possessing any considerable size possess such a small mobility when ionized that they are given a very small velocity by the electric field. On the other hand, the driving force due to ionic streams increases as the mobility of the heavy particles decreases, so that the effect of these streams becomes the predominating one for the larger particles.

(4) PRECIPITATION BY AGGREGATION.

The precipitation due to the formation of an electrical wind or of a corona discharge is accompanied by more or less aggregation and a settling of the larger suspended particles. The cause of this aggregation is not well known, but there is no doubt that the sound waves radiating from the discharge have some effect. The sound waves act in a similar manner to the phenomena in the ordinary Kundt's tube, used in measuring the wave length of sound waves.

Some writers claim that electromagnetic waves produce an aggregating effect upon the small water drops in fogs and mists for comparatively long distances from the source of the waves. M. Dibos[11] claims that he has succeeded in clearing fog for distances of 50 or 60 yards by means of high potential discharges from points (140,000 volts). Lodge is said to have made clearances for similar distances by means of electromagnetic waves.

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[11] Soc. Ing. Civ. France, Bull. 60, p. 451, 1907.

It is generally accepted at present that, at atmospheric pressure, ions are not single charged gaseous molecules, but that they consist of many molecules combined with each other in the form of aggregates. The small mobility and coefficient of diffusion of the ions indicate that their mass is much greater than that of the average molecule. As an ion moves through the gas it attracts neutral molecules to it, especially during collisions, and there results an increase in the mean collision frequency of the ion and consequently a diminution in its mean free path. There is, therefore, a constant change in the size of the ionic aggregate as it moves through the gas.

Not only is there an attraction between oppositely charged particles and between charged and uncharged particles, but, under certain conditions dependent upon the relative dimensions of the particles, there may be an attraction[12] when they are both charged positively or negatively.

It is probable that the electrical forces play quite an important rôle in determining the size of the particles in smoke and fumes. Presumably the chemical reactions, such as those taking place in combustion, are between the individual molecules. If this is true, the carbon of smoke must exist for a time in the atomic condition. Whether chemical reactions directly produce ions or not, it is true that, under the usual conditions, combustion and all chemical reactions taking place at a high temperature are accompanied by intense ionization. During a considerable part of the time the suspended solid and liquid particles are subjected to the action of intense electrical fields. They may become charged by direct union with ions or by induction, and these electrical forces probably determine, in part at least, the size of the resultant aggregates.

The action of electromagnetic waves upon suspended particles in gases may be of the same nature as the action on the Branly and other coherers made of carbon or metallic filings.

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[12] See various sections in Lord Rayleigh's and Lord Kelvin's Collected Papers; Russell, *Phys. Soc. London,* 24, p. 22, 1911; Burton and Weigand, *Phil. Mag.*, 23, p. 148, 1912.

Sound waves cause the particles of smoke or fume to be set into motion. Moving particles [13] that are near each other experience an attraction or a repulsion, depending upon their relative motion. An effect of this kind is shown in the Kundt's tube, where particles of lycopodium or any kind of dust are caused to collect together when stationary waves are produced in the tubes. It has been suggested by Dr. Speyers that a scheme might be devised to clean gases of suspended particles by producing a stationary wave in the gas and providing outlets for the gas between the regions where the particles were caused to collect by the Bjerknes effect.

What rôle electromagnetic and sound waves and the polarizing action of an electrical field play in the electrical precipitation of smoke is not known, but these effects are probably subsidiary.

When a synchronously-driven rotating commutator is placed in the high-tension circuit to produce a unidirectional current, four spark gaps, each two or three millimetres in length, are introduced. It results from this condition that in some respects the active electrodes act as antennæ, emitting electromagnetic waves. Whether these waves aid in electrical precipitation is not at present known. Certainly this is true, however. The introduction of these spark gaps results in increasing the positive brush discharge about the active electrode very greatly.

(5) PRECIPITATION AND IONIZATION.

(*a*) *Electrification of Dust and Sprays.*

In order to test whether fine particles of carbon and sprays from various liquids could be electrified or not, the dust and spray was caused to pass through a region where the electrical field produces intense ionization. The blower or spray nozzle, by means of which the fine particles were blown into the air, had its opening connected to an electrode of an electrostatic machine with spark gaps set so that it would give 45,000 volts. The other electrode was earthed and contained openings through which the spray could be blown upon an electrode, connected to an electroscope. The various kinds of dust and spray were found to be electrified with varying degrees of ease, the numbers representing approximately the relative volume of sprays required in each case to charge an electroscope to the same potential.

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[13] Bjerknes, "Hydrodynamische Fernkräfte."

Substance.	Comparative negative.	Electrification positive.
Calcium oxide dust	1	2
Carbon dust	1	1
Ethyl alcohol	1	.8
Ether	1	.7
Toluol	1	Little effect.

The table shows that some substances, such as toluol, can be given a negative charge, but are difficult to charge positively. Experiments of this kind should throw considerable light upon the mechanism of electrical precipitation. Sprays of non-conducting substances can be electrified when they are passed through regions where electrical discharges are taking place. No means were taken to produce spray particles of the same size except that the same atomizer and air pressure was used for each liquid.

(*b*) *Smoke Deposit Patterns.*

A considerable number of investigators have studied the patterns or dust figures formed by flowers of sulphur, red lead, lycopodium powder, etc. The form of the patterns may be very complex and their explanation has at present only been partially given.

In the present investigation numerous deposits have been made of kerosene and soft coal smoke on paper, on one side of which a high-tension electrode was placed normal to the paper, the smoke of the opposite side of the paper being attracted to the paper and caused to be deposited on it by the electric field. The forms of these deposits were in general found to consist of concentric regions of alternating heavy and light deposit: (*a*) the inner nucleus (.4 or .5 cm. in diameter) consisted of a region of heavy deposit; (*b*) a clear circular region (1.5 cm. inside diameter) surrounded the nucleus, and this may be called the first clear ring; (*c*) a ring-shaped deposit, consisting of comparatively fine particles, followed, the thickness being about .8 cm. (first ring deposit). For strong fields (40 or 60 kilovolts) a second clear ring and a second ring deposit surrounded the first ring deposit.

It was hoped that relations could be obtained between the form of the smoke deposit patterns and some of the properties of the electric field and the discharge from the electrode. As yet no relations of this kind have been obtained, although the deposit pattern is somewhat different for positive, negative, and alternating potential electrodes.

This action of the electric field has been utilized in an instrument designed for continuously recording the amount of suspended matter (such as smoke and fumes) in gases.

(c) *The Spark Potential in Gases from Burning Coal.*

The most important factor that determines the sparking potential in flue gases is the amount of ionization. Experiments[14] with pure gases show that the minimum sparking potential depends upon the mass of gas between the electrodes and changes but little between 20° C. and 600° C. when the gas pressure is kept constant. When the source of the ionization is due to combustion, ionization will generally increase with rise in temperature.

The source of potential used for obtaining the effect of rise in temperature and of the presence of smoke consisted of the Westinghouse transformer connected to the 220-volt, 60-cycle terminals, with a sufficient number of incandescent lamps in the primary circuit to reduce the current to about one ampere. The effective voltage across the terminals of the secondary circuit was about 20,000. The spark in air under room conditions was oscillatory and was about 28 mm. in length for the kind of electrode used (electrodes 3 mm. in diameter with conically-shaped ends).

In order to compare the spark gap lengths in air and in the furnace gases, two spark gaps were connected in the high voltage circuit in parallel, one in air (A) and one in the gases S_2 G_2 drawn from the furnace. Only S_2 G_2 is shown in Fig. 1. The length of the gap S_2 G_2 was made as great as possible without causing sparking in A. This length corresponds to the length of gap in the flue gases under the given conditions for a sparking potential of 20,000 effective volts.

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[14] Earhart, *Phy. Rev.*, 30, p. 293, 1909; 31, p. 652, 1910

Experiment 1.—Gap A, 26 mm. in length. Draft in pipe above which is located gap S_2 G_2, 0.2 inch water.

Temperature of flue gas. No smoke.	Length of gap S_2 G_2
163° C.	28 mm. partly oscillatory
175° C.	30.5 mm. partly oscillatory
190° C.	30.5 mm. partly oscillatory
200° C.	33 mm. brush discharge
235° C.	34 mm. brush discharge
248° C.	40 mm. brush discharge
250° C.	50 mm. brush discharge

As the temperature increases, and therefore the intensity of the ionization in the gas, the bright oscillatory streamers of the spark decrease in number and the discharge is gradually converted into a brush discharge from each electrode. The brush consists of a violet fan-shaped discharge, and at the higher temperatures this brush discharge lowers the potential sufficiently to prevent any discharge taking place in *A*, even though the gap S_2 G_2 is made very long.

Experiment 2.—Conditions analogous to those in the above experiment, with the exception that the draft is only about 0.1 inch of water. The density of smoke is usually given in terms of the Ringelmann Scale.

Temperature of flue gas.	Length of gap S_2 G_2.	Smoke conditions.
Room conditions,	28 mm.	....
Flue gas 35° C.	35 mm.	....
Flue gas 60° C.	35 mm.	....
Flue gas 90° C.	37 mm.	....
Flue gas 95° C.	45 mm.	....
Flue gas 95° C.	30 mm.	Dense smoke

The effect of smoke is to change the brush discharge into an oscillatory one, like that occurring under ordinary room conditions, although the temperature is not materially lowered. The effect is due to the smoke particles greatly reducing the amount of ionization in the flue gases, the rate of recombination of the ions being greatly increased.

Experiment 3.—At ordinary temperatures the effect of draft is to blow out the spark, and in order to maintain sparking the length of gap must be decreased. As the ionization in the gas increases and as the brush discharge becomes more prominent the effect of change of draft becomes less, as is shown by the following measurements, the gap S_2 G_2 being kept as long as possible without sparking taking place in A.

Draft.	Temperature.	Length of gap S_2 G_2.
0	25° C.	21 mm.
0.1 in. water	35° C.	18.5 mm
0.2 in. water	35° C.	17.5 mm.
0.6 in. water	35° C.	16.5 mm
0.05 in. water	135° C.	19 mm.
0.25 in. water	135° C.	18 mm.
0.4 in. water	130° C.	17 mm.
0.05 in. water	115° C.	19.5 mm.
0.2 in. water	160° C.	18.5 mm.
0.5 in. water	180° C.	20 mm. Brush discharge

Similar changes of draft have very little effect upon the length of the gaps when there is smoke at a temperature of about 200° C.

The above effect of smoke and suspended particles upon the ionization in gases is being utilized as a means of working a monitor that will indicate the presence of suspended matter in gases.

The point discharge between electrodes in smoke, placed as close together as possible without sparking, is interesting, in that it shows the effect of smoke upon the character of the discharge. The following is a short description of the effect produced when the current is rectified:

(*a*) The appearance of the electrical discharge in hot gases or in smoke is the same when the electrodes are connected to a transformer through a rectifier as when connected to an electrostatic machine.

(*b*) In hot gases the discharge from the positive electrode consists of a violet brush of streamers about a centimetre or more in length. The negative brush is much shorter and is more stationary in character. Draft seems to have little effect in changing the position of these brushes. The violet brush discharge produced on electrodes connected directly to the transformer is greatly affected by draft.

(*c*) In smoke the positive and negative brushes are blue in color. Smoke is rapidly deposited on the positive electrode to a thickness of 6 or 8 mm., the end of the deposit being blunt. The positive brush distributes itself over the deposit of soot. The deposit on the negative electrode is much less, about a millimetre of the end remaining free. The negative brush does not spread out like the positive brush.

(*d*) At the base of the negative brush bright, scintillating points appear. These are probably due to small particles of carbon being heated to incandescence. It may be that it is in this way the end of the electrode is kept free of smoke. Nothing of this kind takes place on the positive electrode.

(6) THE ELECTRICAL WIND.

It has been shown by Townsend that when an ion is given a sufficient velocity by an electrical field it will ionize molecules on collision with them. For a given pressure of a gas there will be a certain minimum value of the electric field required to give the ions sufficient velocity to produce other ions by collision. This phenomenon is known as secondary ionization and is generally considered to be the process by means of which the ionization of sparks, corona discharges, etc., is produced. In the region of a point charged to a high potential the electric field will be very intense. If this field is sufficiently intense it will cause the small number of ions (initially in the gas before the field was produced) present to move with sufficient velocity to produce secondary ionization. Ions having a sign of charge opposite to that of the point will move to the point and give up their charge. Ions having the same sign of charge as the point will be repelled by it, and these will form ionic streams flowing from the point.

The term ion is applied to any small particle ranging in size from that of ordinary dust or smoke particles, visible to the eye, to particles of molecular magnitude. The force acting upon an ion of charge e in an electric field of strength E will be Ee and the velocity of the ion will be kE, k being the velocity of the ion for a potential gradient of 1 volt per cm. Among the various theoretical values given to k is the formula of Langevin[15]:

$$k = \frac{eL}{MV}$$

M is the mass of the ion, L the mean free path of the ion, and V is the mean velocity of the ion due to its thermal agitation.

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[15] *Ann. de Chim. et Phys.*, p. 289, 1903.

The value of k, the mobility of the ion, or the velocity with which it moves in a field of unit intensity (a potential gradient of 1 volt per cm.) ranges from 1.5 cm. per second for ions of molecular size to 0.003 cm. per second for the larger ions existing in the free air. The mobility of charged dust and smoke particles is probably much less than 0.003 cm. per second. In the electrical precipitation of dust and smoke the potential gradient is of the order of 5,000 volts per cm. For ions with a value of $K = 0.003$, this value of the electric field would give a velocity of one or two centimetres per second. This velocity is too small to cause ions of this kind to be precipitated. As ordinary ionized smoke and dust particles have a smaller value of k than the above, it is seen that this action of the electric field will not be efficient in producing precipitation, it being assumed that the charge on the smoke particles is small.

One action of the ionic streams on dust and smoke particles is the same as that of the action of a stream of cathode rays used to turn wheels having thin vanes, the wheels being properly placed in the discharge tube. An action of this kind will increase with an increase in the size of the particle bombarded.

In the above discussion it has been assumed that the value of e is the same for the small ions as for the large ions. While this is not rigidly true, yet in ordinary cases of ionization e probably never rises to any very considerable value, so that in the formula

$$k = \frac{eL}{MV}$$

the only quantity that shows any great variation is M.

As the value of M increases, the size of the ion will increase. Suppose the ion consists of a dust particle that is large enough to be seen. Place such a particle in the path of a stream of rapidly-moving ions produced by a point discharge. It will be subjected to a very large number of collisions by these ions, the number being much greater in the case of a large particle than it would be if the particle was of molecular dimensions. These collisions are all with ions moving in the same direction, hence the particle is given a large momentum in the same direction as that of the ionic streams.

In the region of a pointed electrode charged to a high potential we have seen that the electric field can produce an intense ionization due to ionic collisions with molecules of the gas. This secondary ionization results in the formation of a large number of small ions, for which the value of k is large. Ions of molecular size and of the same sign of charge as the point will be repelled from the point with a velocity of thousands of centimetres per second and in great numbers. These ionic currents will cause some of the air to be dragged with them, so that an " electrical " wind is observed flowing from the point. The wind is accompanied by a mechanical reaction ($-F$) of the point in the opposite direction to that of the wind itself. This reaction is found to be considerably greater for a positive point than for a negative point, the potential being of the same absolute value in each case.

In order to calculate the force (F) acting in any direction, we will consider the ions already formed in the neighborhood. We will assume that the electric field is uniform for the solid angle w. (In actual practice the discharging points consist of asbestos fibres or mica edges interwoven with the conducting wire electrode. If a large number of asbestos fibres are discharging along the wire, w will be quite small.) Let the point be discharging in the z direction and let the density of ions at any point in the solid angle w be ρ_1, the value of the electric field at the point E_z. The stream of ions will be supposed to be confined to the angle ω. The actual appearance indicates that this is the form of the discharge.

The force (F) acting on the ions in the z direction is:

$$F = \int\int\int Ez\, \rho\, dx\, dy\, dz$$

the integration being extended through the angle APB. If V_z is the z component of the ions' velocity and k their mobility, then,

$$Vz = kEz$$

The current (i) through any cross section of w is:

$$i = \int\int Vz\, \rho\, dx\, dy$$

Considering k to be constant,

$$F = \int\int\int \frac{Vz}{k} \rho\, dx\, dy\, dz \quad \frac{i}{k} \int dz$$

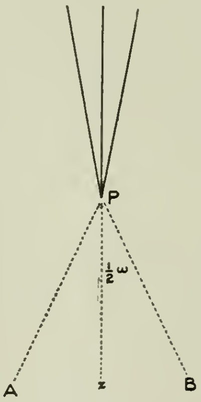
From the above it is seen that the reaction, $-F$, on the point varies inversely as k, if the current is constant. Experiments with single points discharging to electrodes of various forms indicate that the above formula is approximately correct.

For our present purpose the ions having the mobility k are the small ions produced by secondary ionization in large numbers near the discharging electrode, where E_z is very large.

According to the above formula, the force F increases as k decreases or as M increases. F is also increased by increasing the value of i. The aim in electrical precipitation is to increase F, and this is most easily done by increasing i, which in turn depends on increasing ρ.

Now suppose any particle of dust or smoke is placed near the point P in the angle APB (Fig. 2), subtending an angle δw from the point P. The force F_1 acting in this particle due to the ionic streams will be $\frac{F\delta w}{w}$, the ionic stream being supposed to be within the solid angle w. From this formula one has the value of the force acting on any dust or smoke particle:

FIG. 2.



$$F_1 = \frac{i\delta w}{kw}\int dz$$

There are then three forces which aid in driving the suspended particles towards the grounded electrode: (1) the impact of the ionic streams; (2) the impact of the neutral gas particles constituting the electric wind—a sort of hydrodynamic action;

and (3) the direct action of the electric field on the smoke particles when they carry a free charge. These forces are of different degrees of effectiveness for different positions of the smoke particle. In ordinary conditions of ionization the charge on the smoke particles would be small. In electrical precipitation where the ionic streams are flowing in the same direction and contain ions of a single sign, the charge on the smoke particles may become very large and the direct action of the electric field may be the most important force near the end of the smoke particles' path. (This is the view held by Dr. Rosa. In order to test this view, experiments are being made on the charge carried by the smoke particles under these conditions.)

(*a*) *The Cottrell*[16] *Method.*

The kind of discharge used for precipitation may be of two types,—a point discharge producing an electrical wind, or a stream of ions produced by the corona discharge. One of the essential features of the Cottrell process is the use of wire electrodes interwoven with asbestos or mica. Fine threads of asbestos or the sharp edges of the mica cause the production of secondary ionization at lower voltages than could be obtained from the wire electrodes themselves. For this reason it is not necessary to have such accurate spacing of the electrodes to prevent the formation of sparks and arcs. There is usually sufficient moisture or other conducting deposits on the asbestos or the mica to make the surface a fairly good conductor at high potentials. At high temperatures it is difficult to keep the surfaces conducting, and this trouble was experienced in the plant set up by Balaklala Copper Company. The discharging or active electrode is charged negatively, and the suspended matter in the gas is driven to the grounded electrode.

At the plant installed by the Balaklala Copper Company, situated at Coram, Calif., the voltage was stepped up from 2,300 to from 25,000 to 30,000 volts and was then rectified. The rectifying commutators were made so that about 30 or 40 degrees of the maximum part of the wave form was used.

In the Coram plant the active electrodes consisted of two No. 10 iron wires twisted about mica strips about a centimetre wide and with serrated edges. A treating unit consisted of eight rows of these electrodes, twenty-four electrodes being in a row. The units were 30 feet in length, 10 feet wide, and 10 feet high. The grounded electrodes were made of No. 10 sheet iron 6 inches wide and 10 feet high, and were connected directly to the frame of the units themselves. The active electrodes were kept stretched by springs between a system of bus bars supported outside the precipitating chamber on wooden insulators; in order to prevent a deposit from short-circuiting the insulators, a current of air could be passed over the insulators into the precipitation chamber, thus preventing any of the fumes from coming in contact with the insulators. The cleaning of the electrodes was done by mechanical shaking.

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[16] See Cottrell, *J. Ind. and Eng. Chem.*, 3, 8, 1911.

At the Coram plant three units were kept charged by a single rectifier using from 0.3 to 0.4 ampere of current. Each unit treated about 10,000 cubic feet of fumes per minute, the fumes passing through about 30 feet of the electrical field with a velocity of about 5 feet per second. The suspended matter remains about 6 seconds in the electrical field. About 30 pounds of fumes were precipitated per hour per unit.

(7) THE CORONA DISCHARGE.

The luminous discharge from wires and cables carrying a high voltage current has been called the corona discharge by electrical engineers. The lowest voltage gradient per centimetre at which a luminous discharge begins to appear (the "critical corona" voltage, Ec) has been identified as being the same as that at which line losses of power begin to increase rapidly (Ee) and secondary ionization appears at the conductor ("critical ionization" voltage, Ei). The production of secondary ionization in the neighborhood of the conductor causes streams of ions to flow from it into the surrounding gas, producing effects that are similar to those produced by the electrical wind due to a point discharge. The following is a brief summary of the properties of the corona discharge:

(1) In air the positive corona consists of fine branching, bluish-purple brushes darting a centimetre or more from the wire. When the ionic current density is great enough there is a thin, bluish-purple film covering the wire. This is accompanied by a slight buzzing noise. The positive corona is not greatly affected

by the presence of dirt. The brush discharge consists of straight stems of considerable luminosity, from which dart forth twig-like, purplish-violet branches. The pitch of the hissing sound produced depends on the proximity of neighboring conductors.

(2) The negative corona consists of bright, stationary, reddish discharges from 3 to 5 mm. in length. No bright film is present. A loud buzzing noise is produced. The negative brush is but slightly influenced by the presence of surrounding conductors. Dirt decreases the noise and causes the discharge to become more localized.

(3) The presence of asbestos or mica causes the discharge to take place from a comparatively small number of points, the discharge being similar to that of (1) or (2), according to the sign of the charge.

(4) The corona due to an alternating voltage being impressed on the conductor consists of a violet-purplish glow extending several millimetres from the conductor. Whitehead finds that the corona appears and disappears at almost the same voltage for the different parts of the alternating voltage curve. The ions taking part in corona formation are very short-lived.

Placing a glass tube (2 mm. in diameter) over the corona-covered wire decreased the intensity of the corona. The glass tube is surrounded by a pale luminosity about a centimetre in diameter. A loud, sizzling sound is produced.

(5) The introduction of an oscillatory spark in series with the corona discharging circuit has been found to increase the positive brush discharge very greatly. Using a No. 28 steel wire in an 8-inch cylinder, it is possible to obtain a brush discharge between the wire and the cylinder when the effective alternating-current voltage is less than 30,000 volts. The oscillatory spark gap should only be a few millimetres in length.

(6) The corona discharge produced by current from the rectifier is very similar to that described in (5). This is due to the fact that the current must flow across the air gaps of the rectifier. The luminosity about the corona-producing conductor is much less than is the case when no air gaps are in the circuit.

(7) On high-voltage transmission lines, Peek[17] and others have shown that smoke, fog, sleet, rain, and snow increase the

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[17] *Proc. A.I.E.E.*, 30, p. 1491, 1911.

loss of energy due to corona discharge. *Ee* is lowered, the effect due to snow being much greater than that due to rain. The corona discharge does not prevent the formation of sleet upon the wires.

(8) A heavy wind has been found to be without effect on *Ee*. In the laboratory Whitehead has altered the velocity of the air currents past the corona-covered conductor without changing the value of *Ei*. An air velocity as great as 150 feet per minute was used.

(9) Humidity has been found to have no effect on corona formation. In the laboratory the writer has observed no change in the appearance of the corona as described in (4) and (5) when the region of discharge was filled with water spray.

(10) Rise of temperature lowers the value of E_i, according to Whitehead.[18] He gives a case where E_i is lowered from 71.4 to 66.3 kilovolts by a rise of temperature from 7.4° to 41° C.

(11) The critical surface electrical intensity in kilovolts E_i is related to the diameter of wire (*d* in cm.) at 76 cm. pressure and 21° C. as follows:

$$E_i = 32 + \frac{13.4}{\sqrt{d}}$$

An example [19] of the use of the corona type of discharge is the application of electrical precipitation of the cement dust from the kilns of the Riverside Portland Cement Works, at Riverside, Calif. In this plant the gases to be treated are at temperatures of about 450° C. The cement dust is non-conducting, so that no conducting surface would be formed over the mica or asbestos. The use of the corona discharge requires higher voltages than those used in the point discharge. These voltages range in the neighborhood of 40,000, according to Cottrell. The clearance of dust is in general from 95 to 98 per cent. The construction of the treating units at Riverside is almost identical to those used at Coram. At Garfield, Mr. Rathbone is experimenting on the use of cylindrical electrodes. These produce a much more uniform electrical discharge and subject the suspended matter in the gas to a much more uniform treatment. The diameter of the cylinders is 5 inches.

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[18] *Trans. A.I.E.E.*, 27, 1910; 30, p. 1097, 1911.

[19] Cottrell, *Cement and Eng. News*, vol. 24, p. 99, 1912.

(8) THE PRECIPITATION OF COAL SMOKE.

(1) The presence of a small amount of dirt lowers the critical voltage of corona formation, the corona appearing as bright scintillating points. The presence of a coating of soot upon the surface of the conductor affects the appearance of the corona but little.

(2) The electrical discharges that take place in coal smoke are apparently of the same nature as in air. The fibrous brush discharge, characteristic of the positive corona, is distinctly visible. The glow discharge is of a blue color. This is not due to absorption of violet light by the smoke, for a purplish-violet glow loses none of its characteristic color when viewed through smoke.

(3) The presence of smoke causes an increase in the difference of potential between the inside corona wire and the outside cylinder, while the ionization current is decreased. Schmidt has noted the same effect in the case of cement dust. This is due to the great decrease in the ionization of the flue gases due to the presence of smoke.

(4) Coal and oil smoke is precipitated in the same way as the various kinds of fumes. When precipitation is produced by a point discharge, a unidirectional current is much more effective than an alternating one. (An alternating current produces a greater amount of precipitation when there are rapid oscillations produced in it by a series spark gap.) This is probably due to the fact that the pressure of the electrical wind is very much greater from an electrode kept at a constant potential than from one charged by an induction coil or a transformer.

(5) Very little difference was obtained in the precipitation of dense coal smoke in cylindrical pipes, between an alternating current and unidirectional current, when a similar corona form of discharge was used. The precipitation seemed to be comparatively greater for a dense smoke than for light smoke. From this it would follow that dilution of the fume- or smoke-laden gases should be prevented as much as possible.

(6) The similar action of an alternating-current corona and a unidirectional-current corona as a precipitating agent is to be expected if the corona is practically the same for both parts of the wave form, as was found to be the case by Whitehead.

(7) Clearances of 90 and 95 per cent. have been obtained by passing extremely dense smoke through a corona discharge less than 2 feet in length. These experiments indicate that the greatest efficiency of precipitation can be obtained by keeping the suspended matter from being diluted and by exposing them as much as possible to the streams of ions flowing from the corona by passing the gases through a uniform discharge. Shadows can be obtained from objects placed near the collecting electrodes, indicating that the matter being deposited moves in straight lines.

(8) Some kinds of smoke show selective precipitation, a thin cloud of white or bluish particles coming out from the corona discharge. Part of this is water vapor which may have condensed after the carbon and tarry matter had been precipitated. Whether this selective action is due to a difference in the size of the suspended particles or due to a difference in their composition has not yet been determined, although the former view is the more probable.

(9) The hot gases as they leave the furnace contain a very great number of ions of comparatively great mobility, and the ionization current due to these ions may be quite large. This current has been described in a previous part of this paper. The presence of smoke decreases the number and mobility of these ions very greatly, and hence decreases the current due to this cause. This effect is given in (3). Besides this ionization current, there is the current due to the ions produced in the corona discharge itself. In the section on the electrification of dust and sprays it was shown that these ionic currents charge the suspended particles. It is doubtful, however, if the presence of the particles causes any material decrease in the current due to these ionic streams.

(10) In the section upon the electrical wind it was shown that the force due to ionic streams increased with the increase in the size of the particles. On the other hand, the force on a particle due to the action of the electric field on its charge is independent of the size of the particle. For very fine particles the latter force may give sufficient velocity to be of importance, but for ordinary smoke and dust particles the force due to the ionic streams is the preponderating one.

(11) Using Ryan's formula for the loss of power due to

corona discharge, we find that this is practically the amount of energy actually used in the precipitating plant at Coram. It is very probable that no more nor less energy is required for precipitation than that necessary to produce the corona ionization current.

(12) Precipitation of coal smoke was produced in a 3-inch cylinder (4 feet in length) placed in a horizontal position. The active electrode consisted of a No. 28 steel wire. An alternating voltage was used. The cylinder was heated to redness on the under side by a row of Bunsen burners. Precipitation was then qualitatively just as complete, the soot being deposited upon the upper surface of the cylinder. This experiment would indicate that temperature does not play much of a rôle in electrical precipitation. On the other hand, the state of ionization of the gases probably does play a very important part, as was shown in the measurements on sparking potentials.

(13) The character of the corona discharge is probably very greatly affected by the resistance, inductance, and capacity of the circuit when air gaps are introduced by using a rectifier. The writer hopes to investigate some of the effects produced by the constants of the circuit upon the nature of the ionic streams produced in the corona discharge.

(14) The application of electrical precipitation to the smoke problem has not as yet been tried on a commercial scale. Laboratory experiments indicate that the problem is essentially the same as that of the precipitation of fumes and dust. The use of cylindrical electrodes results in a much more uniform electrical discharge if the active electrode is made the axis of the cylinder. While the brush form of discharge from points is only a good precipitating agent when the current of gas is small, the corona discharge is effective for much greater velocities of the gas containing the suspended particles. Under these conditions the suspended particles need remain but a short time in the region where the corona discharge is taking place so that the size of the precipitation chamber can be greatly reduced. The mechanical difficulties of keeping the electrodes properly adjusted and cleaned are probably as great as the electrical part of the problem.

(9) SUMMARY.

(*a*) The effect of the polarization of suspended particles in a gas results in the aggregation of the particles and increases the ease with which the suspended matter can be removed from the gas by settling or by centrifugal means.

(*b*) Suspended particles in a gas can be ionized and may then be removed from the gas by the action of the electric field. Examples are given of the ionization of particles or various kinds of spray and dust. It is shown how various kinds of smoke-deposit patterns are formed by electric fields that are not intense enough to produce secondary ionization and ionic streams.

(*c*) The presence of suspended particles in a gas increases the rate of recombination of the ions in the gas. Smoke or fumes thus greatly reduce the ionization in gases coming from furnaces, and this reduces the ionic current between spark electrodes placed in the gas. This property of smoke or fumes may be used to indicate their presence in a gas.

(*d*) One of the most effective actions of an electrical discharge in precipitating suspended matter from a gas is that of the force acting upon the suspended particles due to the ionic currents flowing through the gas. These ionic currents are produced by the action of the electrical field upon the ions formed by secondary ionization. The secondary ionization may be produced by a point or by a corona discharge.

(*e*) A brief account is given of the plants that have been built for precipitating the fumes from copper smelters and the dust from cement plants. These were visited by the writer during the summer of 1911.

(*f*) A brief account is given of experiments made by the writer upon the precipitation of carbon smoke. Up to the present practically nothing has appeared in the literature concerning the electrical properties of coal smoke.

DEPARTMENT OF INDUSTRIAL RESEARCH,
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Illuminating Engineering Society.—The Sixth Annual Convention will be held at Hotel Clifton, Niagara Falls, September 16th to 19th. The programme includes papers by Dr. C. P. Steinmetz, Mr. George S. Barrows, Dr. E. P. Hyde, Mr. F. A. Benford, Dr. P. G. Nutting, and others. Inspection tours will be made to power-houses and other development enterprises in the vicinity of Niagara Falls.

Canadium, a New Metal. Anon. (*The Metal Ind.,* ix, 12, 508.)—Canadium was discovered by Mr. A. G. French, in a deposit of platinum metals in one of the gold mines in British Columbia. Canadium is sometimes found isolated and sometimes combined. Canadium is a beautiful white metal, a little softer than gold or silver and melts at a little lower temperature. It does not tarnish from damp, and is not affected by sulphides or iodine. It is much more brilliant, when burnished, than silver or palladium. It is electro-negative to silver, gold and palladium, and is not oxidizable even in the oxidizing flame of a blowpipe. It occurs in the form of metallic, semi-crystalline grains, small rods and scales.

Corrosion of Brass. P. T. Bruhl. (*The Metal Ind.,* ix, 11 and 12.)—This is a well considered paper on the corrosion of brass, with special reference to condenser tubes. The conclusions drawn are:—1. That the presence of air, or an increase of temperature up to a certain point, accelerates corrosion. 2. That iron, nickel and small amounts of lead are injurious. That tin up to 1 per cent., large amounts of lead, and aluminum diminish corrosion. 3. That the inlet pipe and condenser plates should be made of brass. 4. That the condenser should be protected against stray currents. 5. That protective coatings are not recommended. 6. That "spills" greatly increase corrosion. 7. That the tubes should be flushed with clean water after use.

Melting of Carbon. W. Borchers. (*Metallurgie,* ix, 230.)—Using very pure carbon rods supported between the poles of an electric furnace, it is maintained that carbon shows no tendency to melt at the highest temperature attainable. The effects produced are due to the expansion and loosening of the mechanical structure present even in the purest rods, causing them to become less coherent and to break.

The National Bureau of Standards in its general investigation of structural materials is engaged, among other things, in the determination of the physical properties of concrete. At the suggestion of engineers and others, the Bureau of Standards is investigating the cause of cracking in concrete structures, where the necessity for expansion and contraction joints is questioned. For this purpose, reference marks were placed on some of the typical old and new concrete work in Wayne County, Michigan, also at Greenwich, Connecticut. Measurements will be taken from time to time during the summer and winter to determine the expansion or contraction in the concrete caused by temperature variations and the changes of volume which take place during the hardening of the concrete. Similar reference marks are being placed on the lock walls of the Panama Canal and various other structures, from which valuable information will be obtained.

NUTATION AND THE MONORAIL CAR.[1]

BY

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The Brennan apparatus for the stabilization of the monorail car is subject to the phenomena of nutation, as of course are all rotating bodies. So far little attention seems to have been paid to this part of the theory. That the nutational vibration may very possibly reach considerable magnitude and violence is suggested by the performance of a common laboratory model shown in Fig. 1. If a weight be attached suddenly, so as to exert a force in the direction of the arrow, the resulting nutation is very marked, having considerable amplitude and a period so long that the undulatory nature of the combined precession and nutation is very apparent. This behavior is due to the fact that the moment of inertia, about the axis of precession, of the mass which partakes of the precession is large compared with the angular momentum of the rotating wheel. A similar situation obtains in the case of the monorail car. Adjustments of the inclination of the car to a change of load or other external forces are accomplished by a precessional motion which takes the form of a rotation of the car and contents about the rail as the axis of the precessional motion. The moment of inertia of the car and its contents with respect to the rail is a large quantity, and it ought not to be presumed that the nutational vibration can be disregarded. The following study of this matter results in formulas which describe the combined precessional and nutational motion, and numerical examples are worked out for an assumed case to illustrate the application of the formulas and to show how far this portion of the theory will govern the design of the gyro-stabilizing system.

Fig. 2 represents in schematic outline the car and stabilizing device. The pair of flywheels with axles horizontal which Mr. Brennan uses are replaced by a single flywheel with vertical axle. This is undoubtedly the more satisfactory arrangement in practice as well as the more convenient for theoretical investigation.

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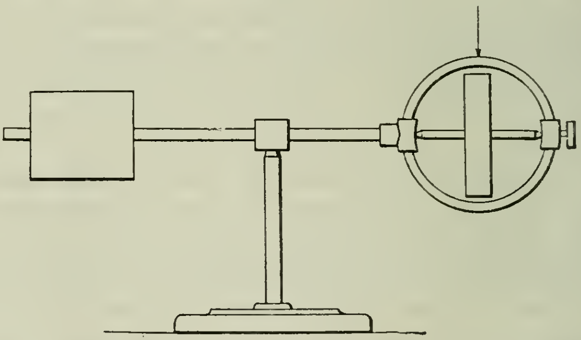
[1] Communicated by the Author.

The process of readjustment of the equilibrium of the car is as follows: Suppose the car to be standing upon the track as shown in the figure with the axle of the flywheel vertical and with no external disturbing forces acting. Then suppose a disturbing force applied at *A* so as to produce a couple C_d which tends to overturn the car. This disturbing couple will be resisted by the gyro-action of the flywheel so that the car will not tip to any considerable extent in the direction in which it is urged by the disturbing couple. This statement implies the rigidity of materials and in particular the absence of spring mounting of the gyro-apparatus upon the car or the car upon the trucks.

FIG. 1.

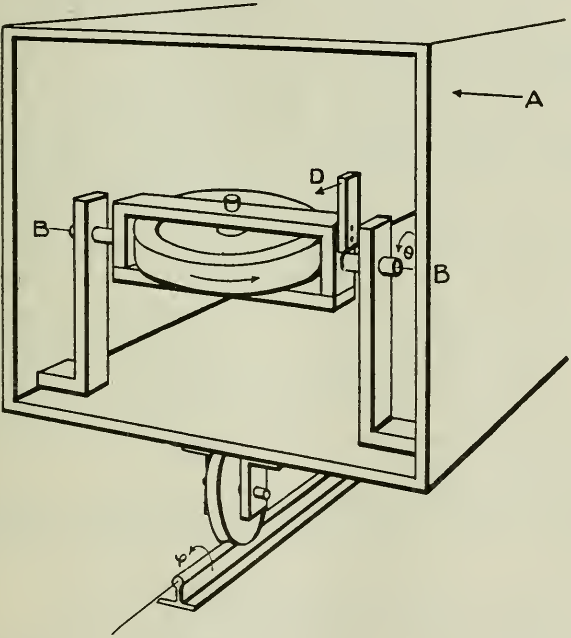


The effect of such springs is by no means unimportant, but it should be treated in a separate discussion after the simpler case now under consideration has been disposed of.

The disturbing forces may be imagined to come into existence suddenly or gradually. In either case the gyro-resistance exerted by the flywheel to prevent the car from yielding to the disturbance will be accompanied by a precession of the flywheel about the axis *BB*, and a nutation. The latter is a periodic motion and may be resolved into two components, one a periodic angular motion of the flywheel and its frame about the axis *BB*, and the other a periodic angular motion of the car and its contents about the centre of the circular section of the rail.

The precession would soon carry the wheel and frames through an arc of 90° about the axis *BB* and the flywheel would then offer no further resistance to the disturbing forces, allowing the car to tip over to the left. To prevent such an event a control device is provided. This device exerts a force at *D*, which produces a couple C_c tending to turn the flywheel and frame about the axis *BB*. This couple, due to the action of the control device, may be thought of as coming into existence gradually or suddenly. In either case it results in a combined precessional and nutational motion. The precession turns the car with its contents about the centre of the rail toward the right, and the nutation which is periodic may be resolved into two components, one a periodic rotation of the flywheel and frame about the axis *BB*, and the other a periodic rotation of the car and its contents about the rail.

FIG. 2.



So soon as the precessional motion described in the last paragraph has turned the car far enough to the right so that the couple due to the weight of the car overbalances somewhat the disturbing couple C_d, the control devices cease to act, the car ceases to turn toward the right and the flywheel returns toward its normal position. This return of the flywheel toward the normal position is due to the overbalancing of the disturbing couple by the gravity couple. As the flywheel approaches its normal position a small force exerted by the control device at D in the direction opposite to that shown in the figure turns the car by precession slightly to the left into a position such that the gravity couple balances the disturbing couple and the car is in equilibrium again with the flywheel in its normal position.

Thus we have described the process of readjustment of equilibrium of the car to any disturbing force, except that nothing has been said about the disappearance of the nutational motions. These vibrations must be destroyed by some shock absorbing device.

Nutation arises whenever any couple tending to change the direction of the axle of the flywheel comes into existence or ceases to act. The violence of the nutation depends upon the magnitude of the couple and the suddenness with which it is applied or discontinued. The most vigorous nutation would arise when the external disturbing couple is applied suddenly (as for example when the car strikes a curve when running at high speed) or when the control device suddenly exerts a powerful force at D, or suddenly ceases to act after having exerted such a force. We shall investigate the nutation that occurs at the beginning of the process of readjustment, *i.e.*, when the disturbing force is applied and when the couple due to the action of the control device is applied.

Suppose the car in equilibrium in the upright position with the flywheel in the normal position as in Fig. 2.

Let $I =$ moment of inertia of the flywheel about its axle.
$\omega =$ angular velocity of the flywheel about its axle.
$N = I\,\omega =$ angular momentum of flywheel.
$J =$ moment of inertia of car and contents about rail.
$j =$ moment of inertia of flywheel and frame about the axis BB.
$Q =$ weight of car and contents in pounds.
$H =$ height of centre of gravity of car and contents above the rail axis.
$C_d = K =$ disturbing couple applied instantly.
$\theta =$ angular displacement, from normal position, of flywheel and frame about the axis BB.
$\varphi =$ angular displacement of car and contents about the axis of the rail.

The equations of motion are then

$$J\frac{d^2\phi}{dt^2} = K + QH\sin\phi - N\cos\theta\,\frac{d\theta}{dt}$$

$$j\frac{d^2\theta}{dt^2} = N\cos\theta\,\frac{d\phi}{dt}$$

The last term in each equation is due to the gyro-resistance (see Spinning Tops, etc., by H. Crabtree, p. 44, or Theorie des Kreisels, by Klein and Sommerfeld, vol. iv, par. 1). The factor cos appears in the first of these terms since the axis of the couple $N\frac{d\theta}{dt}$ makes the angle θ with the rail. The factor cos θ appears in the second of these terms because the component of N perpendicular to the rail is the only portion of it that is effective in resisting rotation about the rail.

Since we are investigating the nutation which occurs at the beginning of the readjustment of equilibrium when the angles φ and θ are very small we may set

$$\sin\phi = \phi$$
$$\cos\theta = 1$$

and the equations become

$$\text{(1)}\qquad \begin{aligned} \frac{Jd^2\phi}{dt^2} &= K + QH\phi - \frac{Nd\theta}{dt} \\ j\frac{d^2\theta}{dt^2} &= N\frac{d\phi}{dt} \end{aligned}$$

The solution of these equations is of the form

$$\text{(2)}\qquad \begin{aligned} \phi &= a\sin\lambda t + b\cos\lambda t + ct + d \\ \theta &= a'\sin\lambda t + b'\cos\lambda t + c't + d' \end{aligned}$$

The initial conditions are

$$t = 0 \qquad \phi = 0 \qquad \theta = 0$$

$$\frac{d\phi}{dt} = 0 \qquad \frac{d\theta}{dt} = 0$$

$$\frac{d^2\phi}{dt^2} = \frac{K}{J} \qquad \frac{d^2\theta}{dt^2} = 0$$

The remaining relations used in determining the constants are obtained by substituting the expressions (2) for φ and θ in (1) and placing the coefficients of the various powers of t and of $\sin \lambda t$ and $\cos \lambda t$ separately equal to zero. We find:

$$\begin{aligned}
a &= 0 & a' &= -K\frac{N(Jj)^{\frac{1}{2}}}{(N^2-QHj)^{\frac{3}{2}}} \\
b &= -K\frac{j}{N^2-QHj} = d & b' &= 0 \\
c &= 0 & c' &= K\frac{N}{N^2-QHj} \\
\lambda &= \sqrt{\frac{N^2-QHj}{Jj}} & d' &= 0
\end{aligned}$$

The solution is therefore

$$\begin{aligned}
\phi &= -K\frac{j}{N^2-QHj}\cos\sqrt{\frac{N^2-QHj}{Jj}}\,t + K\frac{j}{N^2-QHj} \\
\theta &= -K\frac{N(Jj)^{\frac{1}{2}}}{(N^2-QHj)^{\frac{3}{2}}}\sin\sqrt{\frac{N^2-QHj}{Jj}}\,t + K\frac{N}{N^2-QHj}\,t
\end{aligned} \tag{3}$$

The constant term in the expression for φ is called the "dip." It is the amount that the flywheel would yield to the disturbing couple if precession were steady, *i.e.*, if nutation were absent. The term multiplied by t in the expression for θ is the rate of steady precession corresponding to the disturbing couple K. The periodic terms represent the nutation. The periods are identical, but the amplitude of angular vibration of the flywheel and its frame about the axis BB is greater than the amplitude of vibration of the car about the rail, by the factor

$$N\sqrt{\frac{J}{j(N^2-QHj)}}$$

This is a matter of importance in the design of the control device. Mr. Brennan's letters patent concerning the control device proceed upon the assumption that the rotation of the wheel and frame about the axis BB is a steady precession, whereas in fact it will be a very jerky motion if the disturbing couple is large and quickly applied, as would be the case when a car strikes a curve at a high rate of speed.

The question arises naturally as to the degree of suddenness with which the disturbing force must be applied in order that the nutational vibration may approximate the value given by this solution made upon the basis of instantaneous application. To answer this question let us insert in the differential equations of condition the expression kt for the disturbing couple C_d instead of the expression K used above and solve the modified equations. They are, in the approximate form

$$\begin{aligned} J\frac{d^2\phi}{dt^2} &= kt + QH\phi - N\frac{d\theta}{dt} \\ j\frac{d^2\theta}{dt^2} &= N\frac{d\phi}{dt} \end{aligned} \tag{1a}$$

The solution is now of the form

$$\begin{aligned} \phi &= a\sin\lambda t + b\cos\lambda t + ct^2 + dt + e \\ \theta &= a'\sin\lambda t + b'\cos\lambda t + c't^2 + d't + e' \end{aligned} \tag{2a}$$

The initial conditions are

$$\begin{array}{lll} t = 0 & \phi = 0 & \theta = 0 \\ & \dfrac{d\phi}{dt} = 0 & \dfrac{d\theta}{dt} = 0 \\ & \dfrac{d^2\phi}{dt^2} = 0 & \dfrac{d^2\theta}{dt^2} = 0 \end{array}$$

These, with the equations arising from the substitution of values of φ and θ given in (2a) into (1a), give for the values of the constants:

$$\begin{array}{ll} a = -k\dfrac{J^{\frac{1}{2}}j^{\frac{3}{2}}}{N^2 - QHj} & a' = 0 \\ b = c = 0 & b' = k\dfrac{NJj}{(N^2 - QHj)^2} \\ d = k\dfrac{j}{N^2 - QHj} & c' = \dfrac{k}{2}\dfrac{N}{N^2 - QHj} \\ e = 0 & d' = e' = 0 \end{array}$$

$$\lambda = \sqrt{\frac{N^2 - QHj}{Jj}}$$

The solution is therefore

$$\text{(3a)} \qquad \begin{aligned} \phi &= -k\frac{J^{\frac{1}{2}}j^{\frac{3}{2}}}{(N^2-QHj)^{\frac{3}{2}}}\sin\sqrt{\frac{N^2-QHj}{Jj}}\,t + k\frac{j}{N^2-QHj}\,t \\ \theta &= k\,\frac{NJj}{(N^2-QHj)^2}\cos\sqrt{\frac{N^2-QHj}{Jj}}\,t + \frac{k}{2}\,\frac{N}{N^2-QHj}\,t^2 \end{aligned}$$

The term in the expression for φ which represents the dip is now a linear function of the time, as it should be since the dip is proportional to the disturbing force, which increases with the first power of the time. The second term in the expression for θ is of the second degree with respect to the time since the precession proceeds at an accelerated rate. The terms representing the nutation have the same period as in the former solution, as they should, since the period of the nutation depends upon the mass and dimensions of the car and flywheel and the angular momentum of the wheel. The amplitudes differ from those of the previous solution in that both are multiplied by the factor:

$$\frac{k}{K}\sqrt{\frac{Jj}{N^2-QHj}}$$

which the numerical example will show to be a small quantity unless k is very large as compared with K; that is, unless the disturbing force reaches its maximum effect in a small fraction of a second, this second solution will represent the facts more closely than the preceding one.

So far we have assumed the control device to be inactive. We shall now proceed to investigate the nutational vibrations that would be produced by sudden application of the couple which we call C_c due to the action of the control device. It will be remembered that the control device exerts its force after the application of the external disturbing force, so that the vibrations due to this latter force would perhaps be in progress when those due to the action of the control device come into being. However, to avoid unnecessary complication we shall assume that the vibrations due to the application of the external disturbing force have been damped out and a state of steady precession reached before the control device begins to act. The flywheel and car are supposed to be in the position shown in Fig. 2, with the disturbing force acting at A and the flywheel executing the corresponding precessional motion about the axis BB.

The approximate equations of motion for the cases corresponding to the two discussed above are:

For instantaneous application of the couple $C_c = K_c$

$$\begin{aligned} J\frac{d^2\phi}{dt^2} &= K + QH\phi - N\frac{d\theta}{dt} \\ j\frac{d^2\theta}{dt^2} &= K_c + N\frac{d\phi}{dt} \end{aligned} \tag{1b}$$

For gradual application of the couple $C_c = k_c\, t$

$$\begin{aligned} J\frac{d^2\phi}{dt^2} &= K + QH\phi - N\frac{d\theta}{dt} \\ j\frac{d^2\theta}{dt^2} &= k_c t + N\frac{d\phi}{dt} \end{aligned} \tag{1c}$$

The initial conditions are:
For the first case,

$$\begin{array}{lll} t = 0 & \phi = 0 & \theta = 0 \\ & \dfrac{d\phi}{dt} = 0 & \dfrac{d\theta}{dt} = \dfrac{KN\ *}{N^2 - QHj} \\ & \dfrac{d^2\phi}{dt^2} = 0 & \dfrac{d^2\theta}{dt^2} = \dfrac{K_c}{j} \\ & \dfrac{d^3\phi}{dt^3} = -\dfrac{N}{J}\dfrac{k_c}{j} & \dfrac{d^3\theta}{dt^3} = 0 \end{array}$$

For the second case,

$$\begin{array}{lll} t = 0 & \phi = 0 & \theta = 0 \\ & \dfrac{d\phi}{dt} = 0 & \dfrac{d\theta}{dt} = \dfrac{KN}{N^2 - QHj} \\ & \dfrac{d^2\phi}{dt^2} = 0 & \dfrac{d^2\theta}{dt^2} = 0 \\ & \dfrac{d^3\phi}{dt^3} = 0 & \dfrac{d^3\theta}{dt^3} = \dfrac{k_c}{j} \end{array}$$

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* Obtained by differentiating the nonperiodic portion of the expression for θ eq. 3.

The solutions are: for the first case,

$$\text{(3b)} \qquad \phi = K_c \frac{N(Jj)^{\frac{1}{2}}}{(N^2-QHj)^{\frac{3}{2}}} \sin\sqrt{\frac{Jj}{N^2-QHj}}\, t - K_c \frac{N^2-QHj}{N} t$$

$$\theta = -K_c \frac{N^2J}{(N^2-QHj)^2} \cos\sqrt{\frac{Jj}{N^2-QHj}}\, t - \frac{K_c}{2} \frac{QH}{N^2-QHj} t^2 + \frac{KN}{N^2-QHj} t + K_c \frac{N^2J}{(N^2-QHj)^2}$$

for the second case,

$$\text{(3c)} \quad \phi = -k_c \frac{NJj}{(N^2-QHj)^2} \cos\sqrt{\frac{Jj}{N^2-QHj}}\, t - \frac{k_c}{2} \frac{N}{N^2-QHj} t^2 + k_c \frac{NJj}{(N^2-QHj)^2}$$

$$\theta = -k_c \frac{N^2 J^{\frac{3}{2}} j^{\frac{1}{2}}}{(N^2-QHj)}{}^{\frac{3}{2}} \sin\sqrt{\frac{Jj}{N^2-QHj}}\, t - \frac{k_c}{6} \frac{QH}{N^2-QHj} t^3 + \left[k_c \frac{N^2J}{(N^2-QHj)^2} \right.$$

$$\left. K \frac{N}{N^2-QHj} \right] t$$

The vibration periods are identical with those obtained in the former solutions but the amplitudes are greater for the same applied couples. The amplitude of the vibration in the co-ordinate θ is in each case equal to that in the co-ordinate φ multiplied by the factor

$$N\sqrt{\frac{J}{j(N^2-QHj)}}$$

The formulas 3, 3a, 3b, 3c indicate the performance of the car and flywheel when the wheel is near the normal position, *i.e.*, $\theta = 0$. When the flywheel is in any other position the formulas should be modified by the substitution of $N \cos\ \theta_0$ for N, where θ_0 is the value of θ at the instant the couple that produces the nutation is applied or discontinued. That this is the case will be clear when the more rigorous form of the equations of condition is recalled (p. 269). Instead of setting

$$\cos\theta = 1$$

we set

$$\cos\theta = \cos\theta_0$$

which is a better approximation for this case.

As an example of the application of these formulas let us assume that a car of the weight and dimensions of a standard sleeping car is built to run on one rail with a Brennan stabilizing device of the form shown in Fig. 1.

Suppose the weight and dimensions of the car to be such that

$Q = 150{,}000$ pounds.
Distance of centre of gravity of car above centre of rail bulb $= 6$ feet.
Radius of gyration of car about gravity axis parallel to rail $= 5$ feet.

Let the mass of the flywheel be taken equal to 5 per cent. of the mass of the car in accordance with an estimate ascribed to Mr. Brennan, and suppose its radius of gyration to be 6 feet. Such a wheel if made of nickel steel might run at a rate of 1600 r.p.m. We have upon this basis the following values of quantities appearing in the formulas:

$$N = 351200.$$
$$J = 284000.$$

Let us assume $j = \frac{2}{3}\, I = 1398.$

Then $QHj = 1.258 \times 10^9$
$N^2 - QHj = 1.220 \times 10^{11}$

Now suppose this car to be travelling at a rate of 120 miles per hour, and to enter upon a two degree curve over a spiral 400 feet long. The moment of the centripetal force corresponding to the two degree curve would be

302200. foot-pounds.

The time spent upon the spiral would be

2.273 seconds

When the car strikes the spiral the disturbing force would grow at a rate of

132900. foot-pounds per second,

which is the value of k in formula 3a.

Inserting these values in formula 3a, we have for the amplitudes and period of the nutational vibration of the car about the rail

$$\text{Amplitude} = \frac{J^{\frac{1}{2}} j^{\frac{3}{2}}}{(N^2 - QHj)^{\frac{3}{2}}} = 0.^\circ 05$$

$$\text{Period} = 2\pi \sqrt{\frac{Jj}{N^2 - QHj}} = 0.^s 36$$

If the control device were to act so as to incline the car inward at a uniform rate (neglecting the nutational vibration) as the car traverses the spiral its couple would have to be applied instantly with full force and remain constant while the car is upon the spiral. The magnitude of the couple that would be required is obtained from the first of equations 3b as follows. Omitting the periodic term we have

$$\frac{d\phi}{dt} = -K_c \frac{N}{N^2 - QHj}$$

$$K_c = -\frac{N^2 - QHj}{N} \frac{d\phi}{dt}$$

If φ represent the inclination with which a car should round a curve of radius r at v miles per hour, we have the well known relation

$$\tan\varphi_1 = \frac{v^2}{gr}$$

where g is the acceleration due to gravity. For the two degree curve at 120 miles per hour, we find

$$\phi = 18.^\circ 56$$

and dividing this by the time spent upon the spiral we have

$$\frac{d\phi}{dt} = \frac{18.56}{2.273} \times \frac{1}{57.3} = 0.1425 \text{ radians per sec.}$$

which gives

$$K_c = 49{,}510. \text{ ft. lbs.}$$

The amplitude of the nutational vibration of the car corresponding to the sudden application of such a couple is obtained by substituting in the first equation of 3b, namely

$$\text{Amplitude} = K_c \frac{N(Jj)^{\frac{1}{2}}}{(N^2 - QHj)^{\frac{3}{2}}} = 0.^\circ 47$$

the period being as computed above $0^s.36$.

If the car were to vibrate in this manner a point twelve feet from the rail would perform a complete oscillation back and forth through a distance of

2.3 inches

in

0.36 second.

If it be assumed that the control device does not exert its couple instantly, but that the couple grows uniformly with the time at the rate of 50 foot tons per second, the amplitude of vibration would be only

0.°054

that is about one-tenth of the amplitude found above for the case of sudden application of the couple.

As regards the vibration of the wheel and frame about the axis *BB*, its amplitude for any given case is obtained from the amplitude of vibration of the car by multiplying by the factor

$$N\sqrt{\frac{J}{j(N^2-QHj)}} = 14.33$$

Thus the vibration of the wheel and frame about the axis *BB* would have a double amplitude of 13°.4 for the case of instantaneous application of the couple exerted by the control device.

These computations are presented to convey a more definite notion of the magnitudes involved. The assumed weight and dimensions of the car are about those of the heavier sleeping cars now in use. The curvature (two degrees) is conservative for present practice on the best roads. The 400 foot spiral is twice as long as would be used for a two degree curve. The amplitudes of nutational vibration prove to be small and the period is short. It would seem that all harmful effects could be prevented by taking proper care in the design of the car and stabilizing apparatus. The flywheel should be protected from couples that occur in the form of shocks. Means should be provided for damping out the nutational vibration that does arise and the design of the car springs should be such that the car would not vibrate upon them with a period approximating the period of the nutation. Finally, the design of the control device must take into account the vibratory nature of the motion of the wheel and frame about the axis BB. As stated above, this seems to have been left out of account in the design recently patented by Mr. Brennan, which circumstance may very possibly lead to failure of the device to operate satisfactorily when severely taxed.

An incidental result of the numerical computations is to call attention to the very great couple that must be exerted by the control device. It can be shown that the control device must be prepared to exert a couple something like one-half as great as the maximum suddenly applied couple that the car is designed to resist.

Another incidental result of this study of the nutation is the indication given by equations 3c regarding suitable spiral approach to curves. The couple exerted by the control device should not be applied instantly, but should increase uniformly with the time in order that shock and excessive nutation may be avoided. This involves, according to equations 3c, a value of φ (that is an inclination of the car) which increases with the square of the time that has elapsed since the car entered upon the spiral. Since the inclination of the car should correspond to the curvature at each instant, it follows that the curvature ought to increase with the square of the distance measured along the track from the tangent section. In present steam railroad practice the curvature of the spiral increases approximately as the first power of the distance.

Condition of Existence of Arc between Carbon Poles. A. OCCHIALINI. (*N. Cimento,* 2 Ser. vi, 329.)—From a study of kinematographs of the electric arc between carbon poles, it is concluded that under ordinary conditions, with a cold anode, there are two distinct phases in the formation of the arc, the first having the character of a scintillation, the second, termed the *autonomous phase,* that of the arc proper. A cold anode is essential to the existence of the first phase, a hot anode for the second, so that the first prepares the necessary condition for the second. By using a rotating carbon disc as anode the first phase may be prolonged, since the anode does not get warm, and by starting with a hot anode the autonomous phase may be reached without any preliminary sparking. The gas emitted by the anode during the explosive phase gives a line spectrum, that produced during the autonomous phase a band spectrum.

THE TECHNIQUE OF GAS MANUFACTURE.[1]

BY

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UNTIL the Seventeenth Century the store of human knowledge as to the aëriform substances, which are now named gases, was practically confined to that of the more striking physical properties of the atmosphere and its corroding effect upon metals, especially when they were heated.

Van Helmont (1577–1674) was probably the first to understand the existence of aëriform bodies distinct from ordinary air. These he called spirit and in his writings he mentions bodies almost entirely composed of spirit which was fixed and solidified in them. To this spirit he gave the name of "gaz." According to Priestley, Van Helmont derived this name from the German word "geist," meaning spirit, but a later writer claims to have found a statement of Van Helmont connecting the word with "chaos."

Apparently the first published assertion as to the composition of the atmosphere was made in 1665 by Hooke, who stated that air contains a principle similar to, if not identical with, that of nitre. He also seems to have recognized that only a certain portion of the atmosphere is required to support combustion and respiration. The precise experiments on respiration published by Mayow in 1670 greatly strengthened this conception of the complex nature of the atmosphere, but in spite of the incontestable facts he presented this truth was not fully recognized until more than a century afterwards.

Boyle extended the knowledge of the physical and chemical constitution of air by the work described in his treatises published between 1672 and 1692. About 1770 Rutherford demonstrated the existence in the atmosphere of nitrogen and shortly afterwards Priestley separated oxygen from red oxide of mercury, and the significance of this discovery, in relation to the constitution of air, was clearly demonstrated by Lavoisier, who by heating mercury in contact with a measured volume of air showed that about one-fifth of this volume was taken up, with the formation of the red oxide of mercury, and that the remaining four-fifths had all the properties of the "mephitic air," or nitrogen, of Rutherford.

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[1] Address delivered at the Celebration of the Centenary of the Introduction of Gas as an Illuminant, under the auspices of the American Philosophical Society, The Franklin Institute, The American Chemical Society, and The American Gas Institute, in the hall of The Franklin Institute, Philadelphia, on Friday, April 19, 1912.

Hydrogen was recognized as an individual gas by Cavendish in 1766 and its name was given to it by Lavoisier.

During the Seventeenth Century some progress was made in determining the identity of carbon dioxide as distinct from atmospheric air and in recognizing its various occurrences as the result of fermentation and combustion and as collected in subterranean and enclosed places at a low level, and as the cause of the sudden deaths known to occur in such places but previously ascribed to the acts of an evil spirit.

Van Helmont is stated by some authorities to have known the identity of the gases from these sources, but according to others these facts were not fully known until nearly the end of the Eighteenth Century. The composition of carbon dioxide was finally determined by Lavoisier.

The existence of fire damp, the name being obtained from the fact that this "damp" or vapor was inflammable, in connection with marshes and coal seams had been known at an earlier date, but Thomas Shirley seems to have been the first Englishman to examine carefully the properties of this important constituent of illuminating gas, now known chemically as methane, and generally as marsh gas, or carburetted hydrogen. In 1667 he published in the *Philosophical Transactions* an account of his investigation in 1659 of the phenomena occurring in a burning spring near Wigan in Lancashire. Shirley demonstrated that the combustible matter was a gas bubbling through the water, which gas he collected from the ground after the water had been diverted into another channel. After this publication many similar observations were made as to the formation of methane by the decomposition of vegetable matter.

One of the earliest observers of the fact that the distillation of carbonaceous matter yielded a combustible gas was Boyle, who found that when distilled, wood yielded oil, spirit, phlegm (steam), and water. The Reverend John Clayton, in a letter written to Boyle and which, although only published in the *Philosophical Transactions* in 1739, must have been written before Boyle's death in 1691, describes experiments in distilling coal undertaken as a result of seeing gas escaping from a ditch near Wigan which was found to be underlain by coal. He used a retort and obtained first phlegm (steam), then black oil and then a "spirit" which could not be condensed and gradually accumulated until the pressure forced the lute and broke his glasses. The accidental ignition of the escaping gas proved that it was inflammable. By storing some of it in bladders he found that both it and its property of inflammability were permanent.

In 1726 Dr. Stephen Hales distilled wood and coal and noted the toxic effect upon animals of the "air" produced. He states that from Newcastle coal he obtained one-third of its weight of "air," but since this coal, even with improved methods of distillation, yields only one-fifth of its weight of permanent gas some condensable products must have been included in this amount.

In 1767 Dr. Watson published some essays in which he speaks of the giving off of "air" during the distillation of coal.

Even at this comparatively late date, gases were thus spoken of as "air," and although the name "gas" suggested by Van Helmont for these bodies was defined in Macquer's Chemical Dictionary published in 1771 as the "name given by chemists to invisible parts which escape from certain bodies," this name was not used generally until some time after it was adopted by Lavoisier in 1786.

The discovery that the distillation of coal and other carbonaceous substances produced an inflammable and more or less luminous gas was thus made prior to 1690, but it was not until nearly one hundred years later that the idea of using this gas for illuminating purposes was conceived. Then this use seems to have been thought of independently by several persons in different countries at about the same time, and consequently there is a dispute as to who should be accredited as having been the originator of the use of coal gas as an illuminant.

Apparently J. P. Minckelers, a professor in the University of Louvain, in Belgium, in 1784, distilled powdered coal, for the production of inflammable air which he used to fill balloons. In a report advocating the use of coal gas for aeronautical purposes, in which he was particularly interested, he is said to have mentioned the fact that the gas might be purified by being passed through lime water and could then be used for illuminating purposes. It is also claimed that records in the archives of Louvain show that in 1785 Minckelers lighted his lecture room with inflammable air produced by the distillation of coal.

Phillippe Lebon distilled wood and coal in 1786 and in 1799 took out a patent for "a new method of employing fuel with greater utility either for heating or lighting and to obtain certain products therefrom." The apparatus described in this patent was not very practicable and in 1801 he obtained a certificate of additions. In this certificate he calls the apparatus a "thermolampe" and apparently his main idea was to obtain inflammable gas with the object of producing motive power by means of its explosion and little importance was attached to the gas as a means of lighting. For lighting purposes he described a means of consuming the gas inside a glass globe into which gas and air were led by separate pipes and from which the products of combustion escaped by a third pipe. Such a complicated apparatus was not suitable for ordinary use, but his exhibition of lighting by this method, given in Paris in 1802, was written up in glowing terms by the Parisian newspapers and in this way attracted attention all over the Continent of Europe.

The earliest patent taken out in England, in connection with the distillation of coal, was that of Lord Dundonald, for the production of different substances from the distillation of coal, obtained in 1785. His object, however, was the production of tar and while he is said to have lighted the hall of Culross Abbey with crude coal gas in 1787 he apparently did nothing further along the lines of illumination by means of coal gas.

William Murdoch, who is credited in Great Britain and among English speaking countries as being the originator of the use of gas for illuminating purposes, apparently began experimenting along this line at Redruth, Cornwall, in 1792. In that year he distilled coal, peat, wood and other carbonaceous bodies and, being impressed by the quantities of gas given off during the distillation and the facility with which a brilliant light was produced by this means, he made experiments to determine the relative costs of light so obtained and that obtained from oils and tallow. In 1797 he lighted his own premises in Old Cumnock, Ayrshire, with coal gas. Becoming connected with the firm of Boulton and Watt, quite prominently identified with the development of the steam engine, he lighted with coal gas in 1789 one of the principal buildings of their plant at Soho, Birmingham, and in 1802, in celebration of the Peace of Amiens, the Soho works were strikingly and, for the period, brilliantly illuminated by means of that gas.

Apparently Minckelers and Lebon while working with other objects in view preceded Murdoch in their experiments with, and demonstrations of, illumination by means of coal gas, but the latter was the first to work with illumination as the main object.

Through Lebon, however, the man who probably was the greatest factor in hastening the introduction of the public supply of gas became interested in the subject. This man, Frederick A. Winsor, seeing, in one of the European newspapers, a description of Lebon's exhibition was struck by the possibilities of the process and, going at once to Paris, saw the light and tried to obtain from Lebon information as to the method of producing it. It was, however, impossible for him to pay the high price asked and Winsor left Paris disappointed but determined to find out the causes of such important effects and results.

By the next year he had obtained a certain amount of knowledge on the subject and gave in Brunswick exhibitions of the lighting effect of gas produced by the distillation of wood. At this time he was seized with great force with the idea that England was the most favorable field for the exploitation of the process and, acting promptly on this thought, went to London and there gave, in 1804, at the Lyceum Theatre, lectures and exhibitions on gas lighting. Although working under difficulties, and at first without much success, partly because of his extravagant claims, Winsor persisted in his efforts to promote and finance a National Light and Heat Company, and was finally reported to have obtained nearly £50,000, all of which was expended in the furtherance of his plans. In 1809 he lighted with gas a portion of one side of Pall Mall, this being the first public street lighted by means of coal gas.

While Winsor was thus working to interest capital in a company to exploit gas lighting over the whole area of Great Britain, attention was also being called to this means of lighting by the lectures of various chemists, and practical applications of the process were being made in various cotton mills by Murdoch, and by Samuel Clegg. Even with the crude apparatus employed, lighting by coal gas was found to be much cheaper and more brilliant than that obtained, according to the general practice of the day, by the use of candles.

In 1809 Winsor and his associates applied to Parliament for a charter for a company to supply gas over the whole of Great Britain. Murdoch, who claimed that priority of invention entitled him to the charter if any were granted, opposed this application and it was denied, but another, made in 1810 by Winsor and his associates, resulted in the passing of an Act authorizing the king to grant, within three years, to the London and Westminster Chartered Gas Light and Coke Company, a charter covering London, Westminster, Southwark and the adjacent suburbs. The capital was fixed at £200,000 to be raised in full within three years after the granting of the charter, while £100,000 had to be raised before the company could commence operations.

The company finally obtained its charter on April 30, 1812. Its operations were not successful at first, but in 1813 progress began to be made, and by 1815 the company had installed three manufacturing plants and fifteen miles of street mains. Other companies were soon organized and the business of supplying gas progressed so rapidly in Great Britain that by 1829 more than two hundred gas companies had been formed.

The first use of coal gas as an illuminant in the United States is said to have been made in Philadelphia in 1796, but the first definite record of such use in this country is the lighting in 1806 by David Melville of his house in Newport, R. I., with gas made by himself. In 1810 he obtained a patent for "a gas lamp for lighting manufactories, mills, theatres, etc., with hydrogen gas, or inflammable air produced from pit coal," and in 1813 he lighted with gas some mills in the vicinity of Newport.

The first gas company in the United States was organized in Baltimore in 1817 and this was followed by the organization of companies in Boston and New York, but because of the comparative cheapness of other illuminants progress was slow and up to 1830 these were the only cities that had gas works.

I have been unable to find any description of manufacturing apparatus specifically stated to be that employed in the first works of the Chartered Gas Light and Coke Company. It is probable, however, that the apparatus described in "A Practical Treatise on Gas Light," published by Frederick Accum in 1815, as being calculated for lighting towns or large districts of streets and houses, is, even if not exactly the same, very similar to that which was installed in these works, because Accum was the first engineer of the Chartered Company and refers throughout this book to information obtained from Samuel Clegg, who was his successor.

In this apparatus the coal was distilled in cast iron retorts about 15 inches in diameter and 3 or 4 feet long, placed in sets of two in the flues of fireplaces, built under the backs of the retorts, in which coal fires were maintained. The fronts of the retorts opened into a chamber shut off from the operating floor by means of a brick wall through openings in which the work of drawing and charging was done, the coke falling, as it was drawn, through a hole in the bottom of this chamber into a space below the operating floor. The gas leaving the retorts passed through so-called syphon tubes, with a diameter of probably less than 3 inches, into the horizontal condenser, or hydraulic main. The lower end of the syphon tube, or of the dip pipe, was sealed by the accumulation of the liquids condensed from the gas in the hydraulic main until they passed off over the top edge of a partition plate set at a level above that of the bottom of the syphon tube. From this condenser the gas was carried by a take-off pipe to a pipe coil placed in the water in the space between the holder and the tank. After being cooled in this coil, the gas was led into a lime machine while the condensed liquids ran into a tar cistern. In the lime machine the gas was caused to bubble through lime water by which the sulphur compounds were removed. Upon leaving the lime machine the gas was passed through a small washing apparatus placed inside of the holder, from which it escaped into the interior of the latter.

The holder bell probably had a capacity of about 14,000 cubic feet and was made of light sheet iron fastened to a rectangular frame formed of wooden struts and iron bars, while the tank was apparently made by lining with wrought iron the foundation walls of the building in which the holder was enclosed.

The street mains were made of cast iron spigot and faucet, or bell and spigot, pipes, the joints being made with either iron cement or lead.

Service pipes up to a diameter of 1¼ inches were made of tubes of welded wrought iron in 3-foot lengths with wrought iron fittings and screwed joints.

For house piping tubing made either of sheet iron brazed, of lead or of copper with lap-over joints was used. Copper with brass fittings was recommended by Peckston for interior work, with wrought iron tubing for pipe exposed to the weather. The burners were either cockspur, consisting of three round jets, a single round jet, batswing or Argand.

In the 1819 edition of Peckston's "Theory and Practice of Gas Lighting" it is stated that the general mode of charging customers for light was at a certain sum per annum for burners of given dimensions burning from sunset until a stipulated hour, but that this was not satisfactory and that meters for measuring the actual amount of gas used were being gradually introduced, a suitable meter having been brought out in 1817.

In a modern coal gas plant the retorts in which the coal is carbonized are made of clay, are D-shaped with a height of about 16 inches, a width of 24 to 28 inches and a length of 9 to 10 feet for what are known as single retorts, or from 11 to 20 feet for what are known as through retorts. They are set in groups of from six to twelve, each group or bench being heated by means of a generator furnace equipped with recuperators. As a rule the long axis of the retort is horizontal, but that of through retorts is sometimes inclined about 32° from the horizontal and during the last five years the practice of having this axis vertical has been quite largely adopted. In smaller works the coal is charged into, and the coke drawn from, the retorts by hand, but in larger works these operations are performed by machinery. The stand, bridge and dip pipes, through which the gas passes from the retorts to the hydraulic main, have a diameter of 7 or 8 inches. Except for details of construction adopted to insure the sealing of the dip pipes in ammoniacal liquor the hydraulic main remains much the same as in the early works.

The amount of apparatus between the hydraulic main and the holder has been greatly increased from that in the original plants, in order that the removal of tar, the cooling of the gas and the removal of ammonia and of the sulphur compounds may all be efficiently effected.

In the United States the first piece of this apparatus is often a primary condenser, or cooling vessel, employing air as the cooling medium. Either following this condenser or being itself first in the series is an exhauster or gas pump, which relieves the retorts of the pressure thrown by the holders and the friction developed as the gas passes through the apparatus between the exhauster and the holder. From the exhauster the gas passes into a frictional tar extractor, then to the secondary condensers, which are usually water cooled, and then to the washers or scrubbers for the removal of ammonia by solution in water, a washer being a vessel in which the gas is caused to pass through water in small bubbles, while a scrubber is one in which the gas passes in thin streams over surfaces kept wet with water. Leaving the scrubbers the gas goes to the purifiers, where it is freed from sulphuretted hydrogen by means of the chemical affinity between this substance and the oxide of iron which forms the active portion of the purifying material customarily used. After passing the purifiers the gas is measured by large wet meters and then passes to the holders, which, except in the smallest plants, are made with more than one lift and for large plants vary in capacity from 1,000,000 cubic feet to the 15,000,000 cubic feet of the largest holder in the world, that at the works of the Astoria (L. I.) Light, Heat and Power Company.

In some of the larger works rotary scrubbers for the removal of cyanogen and naphthalene are also provided.

The change from the simple plant described in Accum's Treatise to the more complete modern one was made gradually as knowledge was gained concerning the principles involved in the distillation of coal and the subsequent treatment of the volatile products of such distillation. These principles are treated of later.

About 1850 clay retorts began to replace iron ones because of their ability to withstand a much higher temperature, and so make possible a much larger production of gas from a given quantity of coal. The temperature to which the retorts could be heated was increased and economy of fuel obtained by improvements in the design of the furnaces and in the method of setting the retorts. The greatest advance, however, in securing both intensity of heat and economy of fuel came with the introduction of generator firing and the preheating of the air used for combustion by means of the heat contained in the waste gases passing to the chimney. While one of the earliest experiments with gaseous firing for heating retorts was made in 1862 when a Siemens regenerative furnace was used for the purpose at one of the gas works in London, this method of heating was developed on the continent of Europe. The Siemens furnace was too elaborate for general use, but simpler generators and recuperators were soon devised and by 1874 had been adopted in about twenty works. After that time the progress was rapid on the Continent, but up to 1878 there was practically no gaseous firing in either England or the United States. In that year Dieterich furnaces were installed in one of the gas works in Baltimore and experiments, apparently not very successful, were made in several places with other furnaces, but success was obtained in the early eighties and after 1885 the use of generator furnaces and recuperators became general in the larger coal gas plants.

The exhauster, first introduced in 1841, came into general use at the same time as clay retorts. Its use is required because a high pressure on the hydraulic main coupled with the bubbling of the gas through the hydraulic seal on the dip pipes produces in the retorts great fluctuations in pressure and a consequent pulsation of the gas passing off from the coal, which increases very greatly the extent of its contact with the hot walls of the retorts and the destructive breaking down of valuable hydrocarbons by reason of this contact.

The change from the condensing coil placed in the gas holder tank to the form consisting of vertical pipes connected at the top in pairs by return bends and at the bottom into a cast iron box with suitable partitions came before 1841. This form, while still commonly used in Great Britain, has been superseded in the United States by condensers in which the gas passes through an enclosed space traversed by tubes or pipes, the cooling medium being either water or air flowing through these tubes.

It is uncertain when washers and scrubbers were first introduced for the purpose of absorbing ammonia. Washers, apparently placed ahead of the condensers, were used at some works before 1841, but they were tar extractors rather than ammonia extractors. By 1853 tower scrubbers filled with coke were being used but also seem to have been intended more for the removal of tar than for that of ammonia. By 1868, however, the use of tower scrubbers for the removal of ammonia from the gas before it entered the purifiers seems to have been thoroughly established. Rotary scrubbers were introduced shortly after 1880 and have been adopted in the larger plants.

The change from wet to dry methods for the removal of sulphuretted hydrogen and other sulphur compounds, advocated as early as 1817, had not become general in 1841, but the use of dry lime was generally adopted soon after that year and from 1850 on the use of oxide of iron as a purifying material became quite common and in recent years it has been almost the only material employed for this purpose.

The use of station meters began soon after 1815.

The increase in the amount of gas sold and the difficulty of securing ground space in the crowded neighborhoods in which the early gas works were built gradually led to the use of holders of more than one lift and the capabilities of the older methods of guiding holders, that is of providing against their being upset, were soon outgrown. At first holders were guided either by the sliding along a central post of an open pipe with its lower end sealed in water or by means of chains attached at different points around the circumference of the crown and led over grooved wheels to be fastened to a single weight which descended as the holder was raised. Later the guiding was by means of wheels or rollers fastened at points equally distant around the outer edge of the crown and the bottom curb and working against rails or plates attached to the tank wall and to columns, each composed at first either of a single cast iron cylinder, or in some cases of groups of cast iron columns joined together by struts, and later of a single wrought iron cylinder, the columns whatever their form of construction being joined at the top by means of wrought iron girders. The latest style of guide framing, which came in use with the adoption of holders of more than two lifts, consists of structural steel columns joined to each other by several series of horizontal struts and diagonal ties in such a way that the whole frame may be considered as forming a rigid cylindrical cantilever.

At about the same time that the modern system of guide framing was adopted the use of steel tanks built largely above ground in place of the brick tanks built below the level of the ground also began to become general in the United States.

Until recently the comparatively small retorts employed in gas works formed the sole source of coal gas, but now the by-product, or retort, coke oven used in the manufacture of coke also affords a supply of such gas for illuminating purposes. When first introduced all the gas produced by these ovens was consumed in the plant itself, but shortly after 1896 the sale of surplus gas for illuminating and heating purposes was begun in Glassport, Pa., and in 1899 this sale on a large scale was entered into by the New England Gas and Coke Company with a plant at Everett, Mass., supplying gas to Boston and its suburbs. Since that time other plants have entered this field until there are now eleven coke oven plants selling illuminating gas in the United States.

When the surplus gas is to be sold two separate sets of hydraulic mains and condensing and scrubbing apparatus are provided, one handling the rich gas made during the early, and the other the poorer gas made during the latter part of the charge. The rich gas is distributed, while the poorer gas, after being freed from ammonia, tar and benzol, is used for heating the ovens. In one or two plants the ovens are heated with producer gas made from part of the coke and all the coal gas is sold.

Apart from the use of retort ovens, instead of retorts, the treatment in a coke oven plant of the gas which is to be sold does not differ materially from that in an ordinary coal gas plant.

The advantages claimed for coke ovens as producers of coal gas are low labor costs, because of the large weights of coal used in one charge, and the production of a quality of coke which in many localities commands a better market than does ordinary gas coke.

While in Europe the carbonization of coal furnished up to about 1894 practically the sole source of illuminating gas and is still by far the largest source of such gas, in the United States it is second in this field to carburetted water gas. The latter gas is produced by mixing with non-luminous water gas a sufficient amount of oil gas to give the mixture the desired illuminating value.

The decomposition of steam by means of highly heated carbon, with the formation of water gas, was known before the coming into use of coal gas and was experimented upon by Fontana in 1780. After the introduction of coal gas efforts to carburet water gas were begun and in 1847 a patent was taken out in England by Stephen White for the production of a combined coal and water gas. The process covered by this patent was widely discussed by gas engineers of that time and was favorably regarded by some of them, but it proved to be incapable of control and therefore to give very variable results and was not a commercial success. Other processes for the production of carburetted water gas were presented but none of them were successful until in the early seventies T. S. C. Lowe devised in this country the apparatus which, although greatly modified and much improved by other men, still bears his name. The success of this apparatus is due to the principle, first employed in it, of the internal heating of the vessels required for the manufacture of the oil gas needed to carburet water gas, by the combustion in them of the combustible portion of the producer gas formed while the fuel in the water gas generator is being brought up to the temperature necessary for the decomposition of steam.

The Lowe apparatus, in which the water gas and oil gas are made practically in one operation, while the conditions suitable for the manufacture of each can be separately obtained and controlled, in connection with the supply of cheap and suitable carburetting materials afforded by the large production of petroleum and its distillates, made the manufacture of carburetted water gas commercially practicable and economical in the United States and after the installation of the first apparatus in Pennsylvania in 1873 it was rapidly adopted until at the present time it furnishes slightly more than two-thirds of the total amount of illuminating gas made and sold in this country.

The generating apparatus employed in the manufacture of this gas consists of three suitably connected cylindrical vessels constructed of steel plates and lined with fire-clay blocks. The first vessel, called the generator, contains the fuel and furnishes both the producer gas and the water gas required. The other two vessels, in which the oil gas is made, are called respectively the carburetter and superheater and are filled with fire-brick piled in rows from 2 to 3 inches apart, the rows in one tier being at right angles to those in the tiers next above and below. The necessary blast, steam and oil connections are provided and at the top of the superheater there is a take-off pipe with its lower end sealed in water in an auxiliary vessel and having an opening to the atmosphere that can be closed by a self-sealing lid.

A fire having been started in the generator it is gradually filled with coal or coke and this fuel is brought up to a state of incandescence by air blown in under pressure. Because of the deep fuel bed producer gas is formed, the combustion of which in the carburetter and superheater heats the checker brick in these vessels to the temperature required for the gasification of oil. When the proper temperature has been reached in all three vessels the blast is shut off, and the opening into the air from the take-off on the superheater is closed. Steam is admitted to the generator and passing through the fire is decomposed by the combination of its oxygen with the hot carbon and the gas thus formed, consisting principally of carbon monoxide and hydrogen, passes to the carburetter. Oil sprayed in at the top of this vessel is vaporized by the heat and the vapors travel with the water gas through the carburetter and superheater, being converted during this travel into a permanent oil gas. The carburetted water gas thus produced must be cooled and purified as in the case of coal gas except that since it contains practically no ammonia it is not necessary to pass it through apparatus for the removal of that substance.

In the larger gas works the manufacture of both coal and carburetted water gas in conjunction is advantageous. The fluctuations in demand and the seasonal peak requirements can be cared for much more economically with a carburetted water gas plant than with a coal gas one, because of the smaller investment required by the former for a given generating capacity and the greater ease and economy with which it can be put into and taken out of action. In many cases it has been found that even when the cost of carburetted water gas is greater, the cost of a properly proportioned mixture of the two will be less than the average cost of coal gas alone.

A combination plant has also the advantage of giving the company possessing it a better control of the market for coke, the main residual of coal gas manufacture, and placing it in a position to take advantage of fluctuations in the prices of coal and of petroleum because of its ability to vary the amount of gas made from either of these raw materials. Owing to these advantages of the combination plant almost all of the companies in the United States manufacturing more than 50,000,000 cubic feet of gas per year make both coal gas and carburetted water gas.

For many years gas had been made by the distillation, in retorts, of petroleum and other hydrocarbon oils, such as the Scotch shale oils, but this gas was used only for such special purposes as the lighting of railway cars or the enrichment of coal gas, the amount so used forming a small proportion of the total amount of gas distributed. In California, however, the high price of all carbonaceous materials except petroleum led about 1900 to experiments which resulted in the development of a process by means of which is made, from crude petroleum, or one of its heavier distillates, as the sole raw material, a gas very similar in its composition to coal gas but very different from that produced by distilling oil in retorts.

The generating apparatus employed in making this gas is similar to that employed in the manufacture of carburetted water gas and consists of two cylindrical steel shells lined with fire-clay blocks and filled with checker brick. The heat required for the gasification of the oil is obtained by the combustion, by means of air supplied under pressure at suitable points, of oil sprayed in through burners placed around the circumference of the primary generator near its top. When the proper temperature has been reached the blast valves and the stack valve at the top of the secondary generator are closed, the supply of oil through the heating burners is stopped and oil is sprayed in through other burners at the top of the primary generator and also at either the bottom or the top of the secondary generator. Because of the large amount of contact with the highly heated surfaces of the checker brick to which the oil vapors and gas first produced are exposed, from 20 to 25 pounds of carbon in the form of lampblack are set free per 1,000 cubic feet of gas made and the handling and disposal of the carbon, which is used as boiler fuel or as the generator fuel for the manufacture of carburetted water gas to be mixed with the oil gas and, in some places, is made into briquettes and sold for fuel purposes, is a problem connected with this process.

This method of manufacturing gas requires the use of from 10 to 14 gallons of oil per 1,000 cubic feet as compared with about 4 to 5 gallons of oil per 1,000 cubic feet of carburetted water gas and so is economical only where the cost of the extra 6 to 9 gallons of oil is less than that of the 30 to 50 pounds of coal which would be required for making the water gas portion of carburetted water gas.

Another source of illuminating gas which has been availed of to some extent both in the United States and in Germany is the distillation of wood.

Wood gas was made in the Philadelphia Gas Works continuously from 1854 to 1864 and during several years of this period formed about 5 per cent. of the total amount of gas made. It was also the only gas that could be manufactured in several southern cities during the Civil War. In these instances it was made as a substitute for coal gas, the wood being distilled in retorts similar to those used for distilling coal.

At the works of the Mutual Gas Light Company in New York City wood gas was made from 1879 to 1884 as a substitute for water gas. The wood was distilled in L-shaped retorts so charged that gas given off in one part of the retort passed through a mass of heated charcoal in another part. This produced a non-luminous gas which was carburetted with oil gas. A similar retort and method of operation is used in the Riché process recently patented in France, which, however, is claimed to produce gas of a fair illuminating value.

At the present time wood gas is being distributed in a small town in Washington, but apart from special local conditions cannot be produced as cheaply as other gases.

As a result of a wide-spread belief that there was a market for a fuel gas of lower calorific value and cheaper cost than ordinary illuminating gas, attempts were made, between the years 1880 and 1896, in twenty-seven different towns in the United States to distribute either blue water gas or water gas partially enriched with oil gas to give it greater calorific value. The calorific value of the gas so distributed ranged from about 300 B.t.u. per cubic foot for the blue water gas to as high as 450 B.t.u. for the partially enriched gas. Many of these attempts were made after the introduction of incandescent gas lights so that the gas could be used, and its use was advocated, for lighting as well as for fuel purposes, but in no instance was the effort to sell such a gas commercially successful and the companies undertaking it soon went out of business or turned to the manufacture of illuminating gas. This result was reached even in the few instances where this fuel gas, being the only gas supplied in the locality, did not have to compete with any other form of gas.

These attempts to distribute fuel gas of a comparatively low calorific value failed because the cost of a given number of heat units could not be made sufficiently lower than that of the same number derived from a gas of a higher heating and illuminating value to counterbalance the disadvantages of having to consume larger quantities of gas and take a much longer time to do the same amount of work.

No attempt to distribute gas of low calorific value has been made in the United States since 1897, but there is in England a company which was organized about six or seven years ago for the purpose of supplying to a populous manufacturing district "Mond gas" for use by large consumers for power and fuel purposes. "Mond gas" is a producer gas made by passing through a bed of incandescent fuel air mixed with as much steam as it is possible to use without reducing the temperature of the fire below the point at which the decomposition of the steam with the formation of water gas will take place. It contains about 40 per cent. of combustible matter mixed with a total of 60 per cent. of nitrogen and carbon dioxide and has a calorific value of about 156 B.t.u. per cubic foot. The use of the large amount of steam leads to the formation of large quantities of ammonia and the recovery and sale as a residual of this ammonia is one of the principal features of the process, which can only be used on a large scale, and it was thought that the recovery of the ammonia and the large scale working would make it possible to sell the gas at a price at which it would be attractive to users of fuel and at the same time pay a good return on the investment. As late as two years ago, however, the annual report of the company showed that the operating expenses had been barely met and that nothing was being earned upon the investment. The low cost of manufacture and the comparatively small investment in manufacturing apparatus seem to make it impossible to meet the relatively larger distribution costs and investment and still compete with isolated plants.

Analyses of some of the various kinds of gases mentioned above are given in the appendix.

The problem of the destructive distillation of carbonaceous bodies for the production of gas for illuminating and heating purposes has two distinct divisions, the first being the proper application of heat to the material in order to secure the greatest possible quantity of gaseous products of good quality and the second being the proper treatment of the volatile portions of the products of distillation in order to conserve in the gas the greatest possible amount of light and heat giving bodies.

The determination of what constitutes the best possible heat treatment to apply to the raw material is rendered difficult by the complex nature of the reactions which take place when coal or any other material consisting largely of carbon and hydrogen is heated to a high temperature without any access of air.

A clear knowledge of the character of, and the effect of heat upon, the substance called hydrocarbons is requisite for the successful solution of the problem. The hydrocarbons with which the manufacturer of coal gas is concerned belong to five groups, each group consisting of a number of substances which resemble each other in composition but have varying densities and boiling points. These groups are the paraffins with a composition represented by the formula C_nH_{2n+2}; the olefins with a formula of C_nH_{2n}; the acetylenes with a formula of C_nH_{2n-2}; the benzene series with a formula of C_nH_{2n-6}, and naphthalene. In the paraffin group the affinities of the carbon atoms are fully met by the hydrogen atoms and consequently they are known as saturated hydrocarbons and are more inert than the members of the other groups in which the affinity of the carbon is not so fully satisfied by the hydrogen contained in them. In each group the bodies containing the smaller number of carbon atoms in the molecule have the lower densities and boiling points.

The lower members of the paraffin, olefin and acetylene series are all gases, while the higher members of these series and all of the benzene series are liquids, and naphthalene is a solid, at ordinary temperatures and pressures. Certain amounts of the vapors given off from these liquids and from naphthalene can be carried, however, by a gas under ordinary conditions.

The exposure of hydrocarbons to heat produces changes in composition which in general consist of a splitting off of hydrogen atoms and result in the formation of hydrogen and hydrocarbons simpler than the ones acted upon. The exact nature of these changes depends, however, upon the character of the hydrocarbons and the nature and intensity of the heat to which they are exposed.

It is probable that the first products of the heat action are complex hydrocarbons, largely paraffins of high density and boiling point, and that, during their passage through the retort, these by further exposure to heat are broken down into hydrogen and simpler hydrocarbons. The primary products are either liquids or vapors at ordinary temperatures and consequently little gas would be formed if they were permitted to remain in their original condition. On the other hand excessive exposure to heat, and especially to contact with highly heated surfaces, produces secondary reactions resulting finally in the formation of a gas consisting largely of hydrogen through which are diffused hydrocarbon vapors, most of which will be condensed at temperatures and pressures frequently met with during the distribution of gas, and the setting free of carbon which causes much trouble in the generating apparatus. The problem, therefore, is so to adjust the conditions under which the secondary reactions occur as to secure the proper amount of breaking down while avoiding anything in excess of this amount.

Starting with a given amount of carbon and hydrogen in the raw material the heat treatment to which the material should be subjected to obtain any desired character of gas depends upon the following principles: Radiant heat tends to split up complex paraffins into simpler paraffins and olefins and if the exposure to such heat is continued for a sufficient length of time at a sufficiently high temperature the final result is the decomposition of the complex bodies into methane, the lowest of the paraffin series which is not affected by radiant heat, and several of the lower members of the olefin series. On the other hand, heat communicated by surface contact tends to produce from a paraffin, hydrogen and hydrocarbons of the benzene group. In each case the action is accelerated and intensified by increase in temperature of the radiant, or contact, surfaces.

The mixture of olefins and methane has a larger volume and a higher illuminating value than the original paraffins, but is exceeded in both respects by the mixture of hydrogen and benzene vapor. The latter mixture will not contain, however, sufficient hydrogen or other permanent gas to carry the vapor at the ordinary temperatures unless some of the carbon originally present is set free and lost as far as the resulting gas is concerned.

Therefore when a hydrocarbon gas is to be used alone as in the case of the manufacture of coal gas, or is even to be used to enrich another hydrocarbon gas, and illuminating or calorific value is of importance, the gas and vapors escaping from the coal or other material being distilled should be exposed to the action of radiant heat at not too high a temperature but should be protected from contact with highly heated surfaces. When, as in the case of the manufacture of carburetted water gas, the hydrocarbon gas is to be used for the enrichment of a mixture of simple gases, which can carry comparatively large amounts of hydrocarbon vapors, contact with heated surfaces produces good results, especially when the hydrocarbons are exposed to such heat action while being carried by the simple gas, since the presence of that gas arrests the action before it reaches the point at which carbon is set free.

There is no such protecting and carrying gas present in the manufacture of oil gas as carried on along the Pacific Coast and consequently in this process the contact of the hydrocarbons with highly heated surfaces results in the setting free of sufficient carbon to form the hydrogen required to protect the remaining methane and uncombined olefins and carry the vapors of the benzene group. The setting free of a certain amount of carbon and its recovery in the form of lampblack is therefore an inherent feature of this process whatever the character of the oil used as the raw material.

Even when no importance is attached to illuminating value the calorific value of the gas derived from a given quantity of material will be greater the smaller the amount of carbon set free and since methane, one of the most important constituents of coal gas from the calorific standpoint, is not affected by radiant heat but is decomposed by contact with hot surfaces, especially at temperatures above 600° C. (1112° F.) it is still important, when making a hydrocarbon gas by itself, to subject the gas only to the action of radiant heat and avoid as far as possible contact with highly heated surfaces.

Practice in carbonization in gas works had gradually come to agree with these principles even before they were thoroughly understood. Early in the manufacture of coal gas it was recognized that better results as far as the production of gas was concerned were obtained when coal was carbonized in thin layers and at comparatively high temperatures. In working along these lines, however, the portion of the walls of the retort above the charge of coal afforded a large amount of hot surface in proportion to the amount of gas being made and as the temperature at which carbonization was carried on was increased much trouble was experienced from the free carbon produced by the action of this heated surface. To avoid this trouble it was found necessary to increase the weight of the charges placed in a given size of retort and lengthen the time during which the carbonization of the charge lasted until finally as a result of experience with intermittently charged vertical retorts it has become the practice to fill horizontal retorts as completely as possible and make the duration of the period of carbonization sufficiently long to drive all of the gas out of these large charges. The gas, however, is still exposed to contact with hot coke during at least portions of the long period of carbonization and while the use of these large charges has increased both the quantity and quality of the gas produced from a given weight of coal the results obtained from them are probably not as good as could be obtained by the carbonization of coal in smaller charges with the proper exposure of the gas to radiant heat of a low intensity. The use of large charges reduces labor costs, but it is questionable whether a point is not soon reached at which any saving in this direction is more than overcome by a loss in the quantity and quality of the gas made, and it is possible that experiments with horizontal retorts, of much smaller dimensions than those now used, completely filled with coal would show sufficiently better gas results to compensate for increased labor costs, but the continuously operated vertical retort, into which coal is introduced in small amounts at intervals of a few minutes and in which it is possible to regulate very closely the extent to which the gas is subjected to radiant heat, seems to offer the best means of solving the problem of securing the proper heat treatment during the distillation of coal.

Even when the best conditions of heat treatment are attained the gas issuing from the retorts or other generating apparatus is a mechanical mixture, the principal constituents of which are hydrogen, methane and more complex hydrocarbons, some of the latter being vapors, with smaller amounts of carbon dioxide and various impurities, and the second portion of the problem of the manufacture of a hydrocarbon gas is to so treat this mixture that, when the cooling from the high temperature at which it leaves the retort to atmospheric temperatures and the removal of the impurities has been completed, it will retain as large an amount of these hydrocarbon vapors as it is possible to carry to the consumer. The problem of doing this is rendered difficult by the fact that being the vapors of liquids mutually soluble in each other the combined tension of these vapors is much below the sum of the vapor tensions of each and when one of high boiling point is condensed into the liquid form it will carry down with it some of the others whose boiling points are such that, if left to themselves, they could be retained in the gas. It is, therefore, necessary to effect the cooling of the gas in such a way that the condensing out of the vapors which it is impossible to retain in the gas shall be accompanied by as small a loss as possible of those vapors which can be retained. The problem is further complicated by the fact that the employment of the best method of achieving this result is apt with coal gas to lead to trouble in the distribution system from the saturation of the gas with naphthalene, a heavy vapor which condenses directly to the solid form, unaccompanied by other vapors which condensing simultaneously into liquids would dissolve the naphthalene. It is therefore necessary to compromise and suffer a small loss in one direction in order to avoid trouble in another. On the whole, however, the best treatment consists in the removal of the tar, formed by the condensation of the heavier vapors, while the gas is still at a temperature of above 100° F., and a subsequent gradual cooling of the gas to atmospheric temperatures, the condensed liquids formed at different temperatures being removed before any great further drop in temperature has taken place.

When the gas has reached atmospheric temperature it is necessary to remove the ammonia which has not been absorbed by the condensation during the cooling of the gas, of the aqueous vapor which it contained when it left the hydraulic main. This removal is effected by the use of water. After the removal of ammonia the gas must be treated for the removal of sulphuretted hydrogen and the reduction of the amount of other sulphur compounds if this latter amount is excessive. The purifying material commonly used in the United States for the purpose has as its active agent hydrated sesqui-oxide of iron. This combines with sulphuretted hydrogen to form sulphide of iron, which upon exposure to the atmosphere is oxidized with the re-formation of the hydrated ferric oxide and the setting free of sulphur. The efficiency of this portion of the process increases with rise in temperature and in many gas works the gas is heated to a temperature of about 100° F. at the inlet of the purifiers.

The purifiers complete the chemical and physical treatment of the gas, which leaves them fit for distribution, but for economical reasons it is measured and then passed into storage holders before being sent out.

In the early years of the industry the treatment given the raw material and the resulting volatile products was largely governed by rule-of-thumb, but in recent years all the manufacturing steps have been studied scientifically and great progress has been made both in knowledge as to principles and in the practical application of this knowledge. Much remains still to be investigated and there is no reason to doubt that the processes now employed will be improved as time goes on and that the debt of humanity to the gas industry, accumulated during the first century of its existence, will be largely increased during the second.

APPENDIX.

	Coal gas.	Carburetted water gas.	Water gas.	Crude oil gas.	Oak wood gas.
Candle-power	16.7	24.5	—	19.7	26.0
Specific gravity	0.430	0.625	0.53	0.482	0.580
B. t. u. per cubic foot					
Observed	—	626.8	316.8	679.9	—
Calculated	659.7	626.7	302.2	—	—

ANALYSIS.

		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Illuminants—unfixed	C_6H_6	0.80	0.6	—	7.01	6.46
fixed	C_nH_m	4.00	11.4	—		
Carbon monoxide	CO	8.20	31.3	42.8	9.21	26.11
Hydrogen	H_2	45.20	36.1	50.3	39.78	30.44
Marsh gas	CH_4	37.40	12.6	0.4	34.64	33.12
Ethane	C_2H_6	0.70	2.3	—	—	—
Carbon dioxide	CO_2	1.60	3.0	3.0	2.62	0.48
Oxygen	O_2	0.30	0.4	0.4	0.16	—
Nitrogen	N_2	1.80	2.3	3.1	6.58	3.39
		100.00	100.0	100.0	100.00	100.00

Peat-gas Plant. ANON. (*Elect. Rev.,* lxix, 1017.)—This is a producer-gas plant, made by Messrs. Crossley Brothers, installed in a factory at Portadown, Ireland, for power purposes. It consists of two producers, each of 200-horsepower capacity, with a coke scrubber, centrifugal tar extractor, sawdust scrubber (or filter), exhauster fan, and expansion box. It is worked by suction produced by the high-speed fan exhauster, which also delivers the gas to a gas-holder. The feeding hoppers on the producers are larger than those usual with coal fuel, but the gas is similar in constitution to suction gas from Welsh anthracite, though with less hydrogen; its thermal value is 140 B.t.u.'s per cubic foot. The peat has about 26 per cent. moisture as charged into the producer, but in exceptionally dry seasons it is as low as 19 per cent. With an average load of 275 horsepower the fuel cost—allowing 35 s. per week for tar sold—is £4 5 s. ($21), as against £13 16 s. 3 d. ($69) per week for anthracite, which was used in the Mond plant replaced by this peat-gas installation. The tar from the peat amounts to about 5 per cent. of the weight of fuel used. Analysis shows it to contain a small amount of paraffin wax and a considerable proportion of heavy oils distilling above 270° C.

THE ELECTRO-PNEUMATIC BRAKE SYSTEM FOR STEAM ROAD SERVICE.[1]

BY

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THIS equipment was designed for electrically operated trains, in which all vehicles are equipped with a compressor, or have a main reservoir supply line. Since all the braking power for service can be obtained from a 70 # brake pipe pressure, it is obvious that the high main reservoir air can be utilized for emergency applications, thus making it unnecessary to increase the brake pipe pressure. To this end, the equipment described immediately hereinafter was developed, being perfected to a greater degree than any equipment heretofore designed. The service and emergency brakes are separated; that is to say, the mechanism and reservoirs controlling the emergency operation are different from those controlling the service operation. About all that is required of the service parts in emergency is to close and open the exhaust ports.

It will be seen from the above that two valuable features, not realized in any previous brake equipment, are attained: First, a very large and inexhaustible supply of air for the emergency brake; and, second, a high-pressure brake, without the necessity of increasing either the brake pipe or main reservoir pressure beyond that now carried by the most ordinary or least efficient brake equipment.

From these two features greater safety is secured, due to the increased braking power and very economical operation, since a compressor of about one-half the capacity formerly required may be used.

Another valuable feature of this equipment is that it is so designed that, if desired, cars can be equipped with only the service pneumatic portion. Then, as the service conditions change, the quick action portion can be added. Then, for other conditions, the high-pressure emergency feature can be added; then the electro-pneumatic service feature may be added; and, for still more important operation, the electric quick action or emergency features can be added, and all this accomplished without discarding any parts.

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[1] Continued from page 155.

This equipment, then, briefly stated, consists of the most improved form of pneumatic service and emergency brake, interlocked with electric control of both service and emergency operations.

The important features in detail are: Full protection against complete loss of the brake, due to failure of any part of the system; maximum and predetermined flexibility for service operation; certain and uniform action; predetermined and maximum practicable difference between service and emergency braking powers; instantaneous quick action; complete separation of service and emergency features, both electric and pneumatic; full emergency pressure obtainable at will, even after a full service application; automatic emergency when predetermined brake pipe reduction is made after equalization, or when brake pipe pressure is reduced below a predetermined danger point, due to leakage or other causes; brake cylinder pressure maintained in emergency; improved graduated release features.

The quick action feature of the equipment is different from previous types of brake apparatus, in that brake pipe air is vented to the atmosphere in emergency operation, instead of to the brake cylinder.

The quick recharge and graduated release features not only add to the flexibility of control, but also insure an additional factor of safety, because the inherent operation of the apparatus is such that the brakes must be either set or the system recharged ready for prompt application when desired.

Protection against complete loss of brake is insured, since the pneumatic and electric systems are operatively interlocked. While the brakes are being controlled electrically (which is the normal condition), the pneumatic control is held in reserve, without its efficiency in any way being impaired by electrical operation. Consequently, if the electric service control should partially fail from any cause, all the brakes would apply automatically and without the necessity of the motorman even becoming aware of the fact. Therefore, the difference between the electric and pneumatic action is merely with respect to promptness and uniformity on the train as a whole.

The brake application is brought about electrically in the same manner as when applied pneumatically, *i.e.*, by making a brake pipe reduction, in response to which the operation of the mechanism directly controlling the flow of air from the auxiliary reservoir to the brake cylinder takes place in the same manner and produces the same results in either case. The only difference is that in making the pneumatic service application the brake pipe reduction occurs at one point—the brake valve—while when operating electrically, the service application magnet valves make the brake pipe reduction at the proper rate, and simultaneously on each car in the train, which insures a brake application throughout the train in the shortest possible time. The failure of one or more of the application magnets to operate results simply in the brake pipe reduction taking place through the other service magnet valves, or possibly through the brake valve as well. Electric control also adds to the flexibility of the operation.

Certainty and uniformity of service action, combined with protection against undesired operation, due to the inevitable fluctuations of the brake pipe pressure or small brake pipe reductions, is provided for in the design of the valve, which insures that the equalizing piston will move so as to close the feed groove on the slightest brake pipe reduction, and then the necessary and proper differential must be built up to move the parts to service position, as the brake pipe reduction is continued.

The maximum difference between service and emergency braking powers is possible, since the maximum cylinder pressure in service is determined by the equalization of the auxiliary reservoir and brake cylinder, whereas the emergency brake cylinder pressure is determined by the pressure in the main reservoir, and not by the auxiliary reservoir pressure, thus giving the effect of a high-speed brake with low-brake pipe pressure carried.

Instantaneous quick action is obtained whether originating at the brake valve or at any point in the train. This follows from the fact that the emergency action is subject to the movement of the emergency switch on each car, as well as the brake valve movement. The same protection exists for emergency as for service application, viz., that if the electric emergency feature of the equipment becomes inoperative for any reason, the pneumatic emergency operation occurs automatically, and, as this function cannot be impaired any more than the emergency action of the ordinary quick-action automatic brake, it follows that absolute protection against complete loss of the brake is insured.

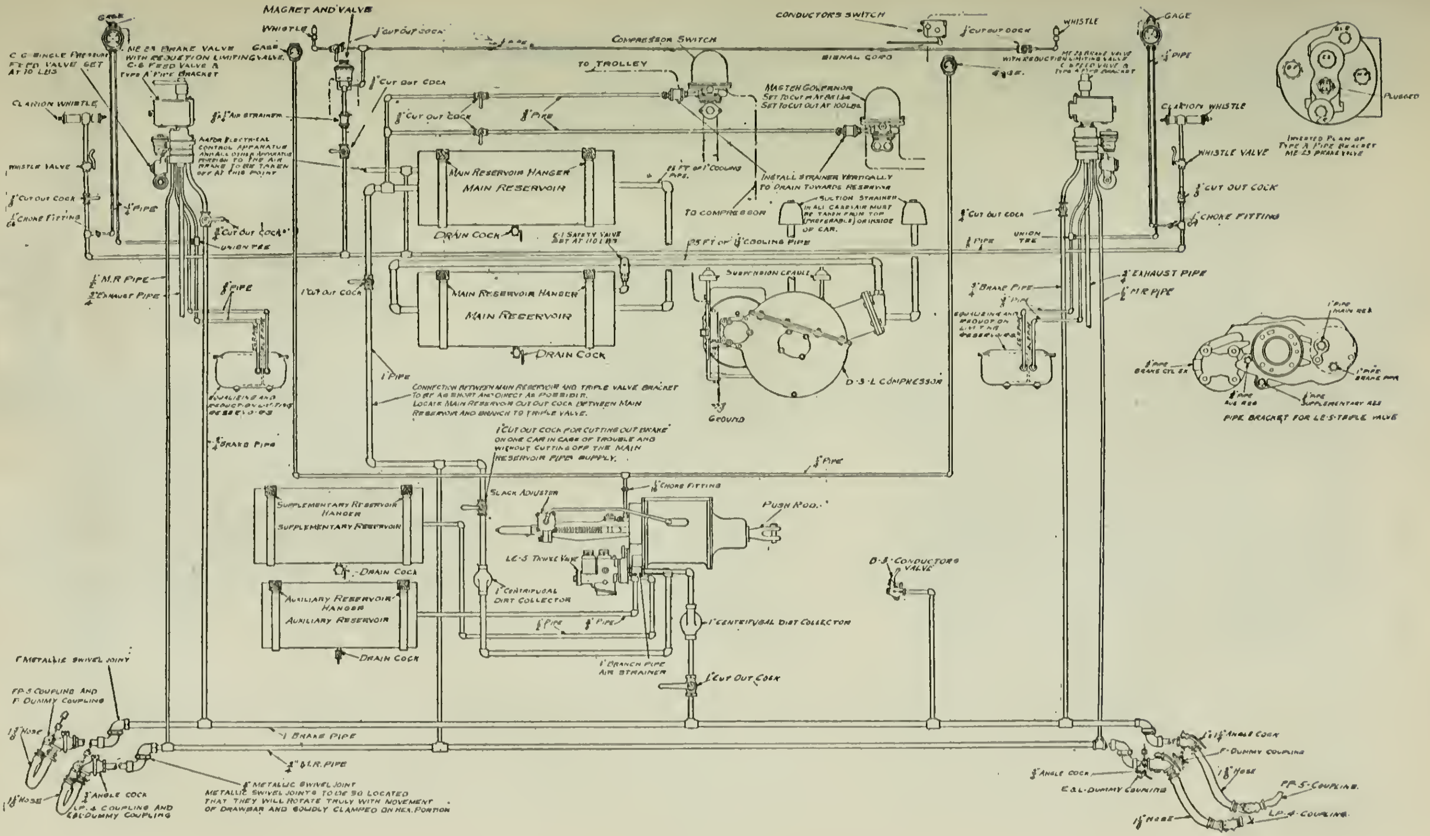
The complete separation of the service and emergency functions permits the necessary flexibility for service applications without impairing in the least the emergency features of the equipment, and eliminates the possibility of undesired quick action in so far as the triple valve service action is concerned. It also insures the obtaining of emergency at any time, no matter what service application has been previously made.

Fig. 15 shows the piping diagram of the equipment, which pneumatically consists of the usual combination of auxiliary reservoir, triple valve, and brake cylinder, with the addition of a supplementary reservoir. The functions of the auxiliary reservoir and brake cylinder are similar to those of the ordinary quick-action automatic brake. The supplementary reservoir assists in obtaining graduated release and the quick recharge of the brake.

Fig. 16 shows the wiring diagram. Electrically, the equipment comprises the usual application and release magnets, with their attached valves, controlling the electric service application and release of the brakes. In addition to these, there is a third magnet, the emergency application magnet, with its valve, controlling the operation of the emergency parts of the triple valve. The emergency switch might be called the connecting link between the pneumatic and electric emergency features of the equipment. It serves as a circuit closer to start the electric transmission of quick action throughout the train, when originating pneumatically.

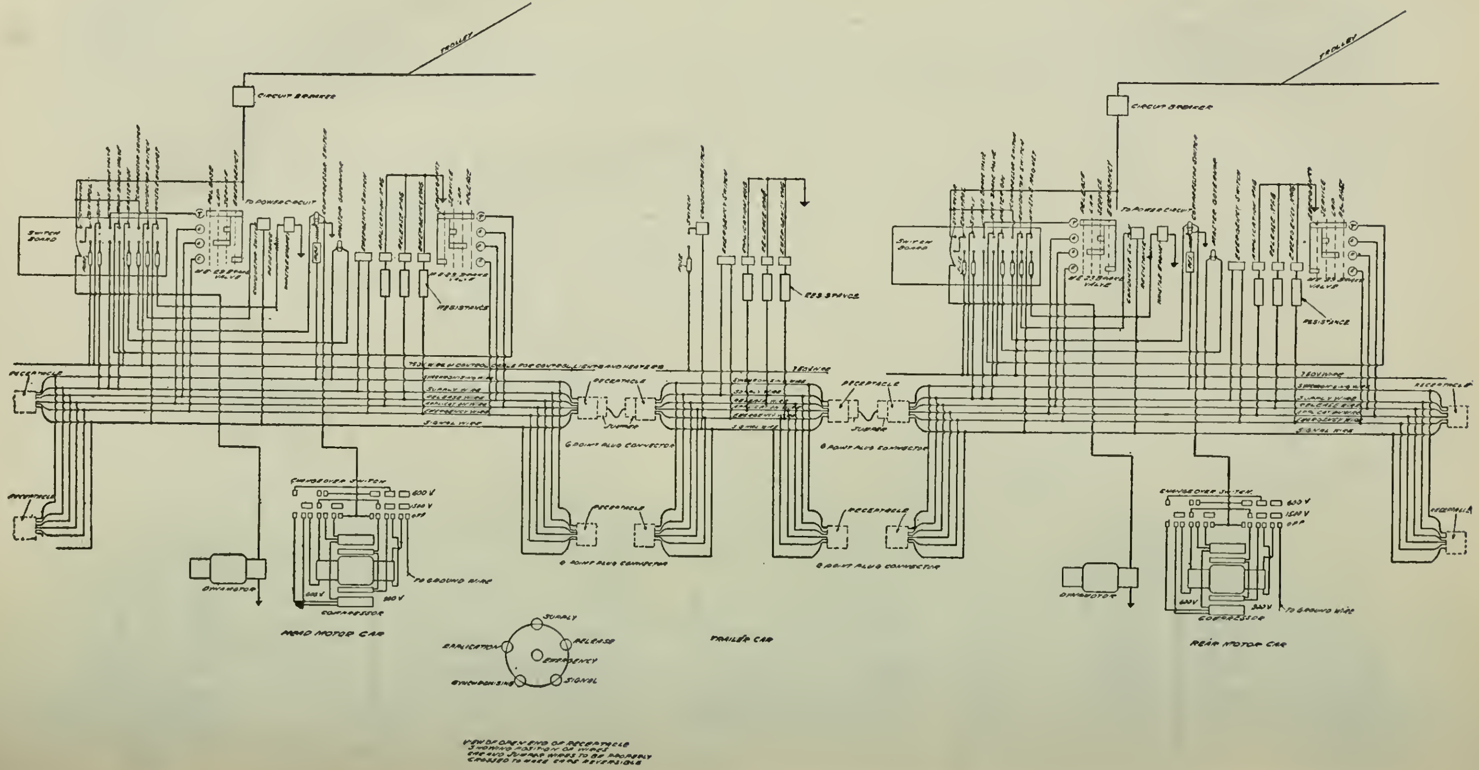
The real distinct and novel features of this equipment are embodied in the brake valve and triple valve.

Fig. 17 shows the operating valve for this equipment, which is composed of two distinct parts, one electrical and the other pneumatic. The electrical features are placed above the pneumatic, and consist of:—a rotary drum, having four contacts


GAGE
MAGNET AND VALVE
WHISTLE
½" CUT OUT COCK
ME 23 BRAKE VALVE WITH REDUCTION LIMITING VALVE. C-6 FEED VALVE & TYPE A PIPE BRACKET
C G SINGLE PRESSURE FEED VALVE SET AT 70 LBS
GAGE
CLARION WHISTLE
½" CUT OUT COCK
⅜ ½" AIR STRAINER
WHISTLE VALVE
AFTER ELECTRICAL CONTROL APPARATUS AND ALL OTHER APPARATUS FOREIGN TO THE AIR BRAKE TO BE TAKEN OFF AT THIS POINT
⅜" CUT OUT COCK
¼" PIPE
1/64" CHOKE FITTING
¾" CUT OUT COCK
UNION TEE
½" M.R PIPE
¾" EXHAUST PIPE
⅜" PIPE
1" CUT OUT COCK
EQUALIZING AND REDUCTION LIMITING RESERVOIRS
¾" BRAKE PIPE
CONDUCTORS SWITCH
COMPRESSOR SWITCH
TO TROLLEY
SIGNAL CORD
½" CUT OUT COCK
⅜" PIPE
MASTER GOVERNOR SET TO CUT IN AT 85 LBS SET TO CUT OUT AT 100 LBS
INSTALL STRAINER VERTICALLY TO DRAIN TOWARDS RESERVOIR
SUCTION STRAINER IN ALL CASES AIR MUST BE TAKEN FROM TOP (PREFERABLE) OR INSIDE OF CAR.
TO COMPRESSOR
25 FT OF 1" COOLING PIPE
25 FT OF 1¼" COOLING PIPE
MAIN RESERVOIR HANGER
MAIN RESERVOIR
DRAIN COCK
E-1 SAFETY VALVE SET AT 110 LBS
MAIN RESERVOIR HANGER
MAIN RESERVOIR
DRAIN COCK
SUSPENSION CRADLE
D-3-L COMPRESSOR
GROUND
1" PIPE
CONNECTION BETWEEN MAIN RESERVOIR AND TRIPLE VALVE BRACKET TO BE AS SHORT AND DIRECT AS POSSIBLE. LOCATE MAIN RESERVOIR CUT OUT COCK BETWEEN MAIN RESERVOIR AND BRANCH TO TRIPLE VALVE.
1" CUT OUT COCK FOR CUTTING OUT BRAKE ON ONE CAR IN CASE OF TROUBLE AND WITHOUT CUTTING OFF THE MAIN RESERVOIR PIPE SUPPLY.
⅜" PIPE
1/16" CHOKE FITTING
SLACK ADJUSTER
PUSH ROD.
SUPPLEMENTARY RESERVOIR HANGER
SUPPLEMENTARY RESERVOIR
DRAIN COCK
LE-5 TRIPLE VALVE
1" CENTRIFUGAL DIRT COLLECTOR
AUXILIARY RESERVOIR HANGER
AUXILIARY RESERVOIR
DRAIN COCK
⅜" PIPE
⅜" PIPE
1" CENTRIFUGAL DIRT COLLECTOR
1" BRANCH PIPE AIR STRAINER
1" CUT OUT COCK
D-5 CONDUCTORS VALVE
WHISTLE
½" CUT OUT COCK
GAGE.
ME 23 BRAKE VALVE WITH REDUCTION LIMITING VALVE C-6 FEED VALVE & TYPE A PIPE BRACKET
GAGE
¼" PIPE
CLARION WHISTLE
WHISTLE VALVE
⅜" CUT OUT COCK
1/64" CHOKE FITTING
¾" CUT OUT COCK
UNION TEE
⅜" PIPE
¾" EXHAUST PIPE
¾" BRAKE PIPE
½" M R PIPE
⅜" PIPE
EQUALIZING AND REDUCTION LIMITING RESERVOIRS
PLUGGED
INVERTED PLAN OF TYPE A PIPE BRACKET ME 23 BRAKE VALVE
1" PIPE MAIN RES
⅜" PIPE BRAKE CYL EX
1" PIPE BRAKE PIPE
⅜" PIPE AUX RES
½" PIPE SUPPLEMENTARY RES
PIPE BRACKET FOR LE-5 TRIPLE VALVE
1" METALLIC SWIVEL JOINT
FP-5 COUPLING AND F DUMMY COUPLING
1⅜" HOSE
1⅜" HOSE
¾" ANGLE COCK
LP-4 COUPLING AND E&L DUMMY COUPLING
1" BRAKE PIPE
¾" M.R. PIPE
¾" METALLIC SWIVEL JOINT
METALLIC SWIVEL JOINTS TO BE SO LOCATED THAT THEY WILL ROTATE TRULY WITH MOVEMENT OF DRAWBAR AND SOLIDLY CLAMPED ON HEX. PORTION
1 1¼" ANGLE COCK
F-DUMMY COUPLING
1⅜" HOSE
FP-5-COUPLING.
¾" ANGLE COCK
E&L-DUMMY COUPLING
1⅜" HOSE
LP-4-COUPLING.

Piping Diagram.

FIG. 16.



Wiring Diagram.

attached to the same shaft as the rotary valve; and corresponding contact fingers on the body of the valve. The upper finger is connected direct to the trolley, the second to the release magnet line, the third to the application magnet line, and the lower one to the emergency magnet line.

This valve not only has the electric control features embodied, but the pneumatic features are developed to a high degree. The pneumatic improvements in this valve over the ordinary automatic brake valve are: The limiting of the service brake pipe reduction to a predetermined value by means of a reduction limiting valve; the prevention of overcharge of the equalizing reservoir, obtained by the use of a collapsible equalizing discharge piston; the quick response of brake pipe reduction obtained by the combination of direct and equalizing piston exhaust ports.

The valve has six positions, viz., release, holding, handle off, lap, service, and emergency.

Unlike previous designs of electric pneumatic brake valves, the position of the handle is identical for the electric and pneumatic service. With the electric features operative, the service magnet valves reduce the brake pipe pressure on each individual car at the desired rate, but if the electric control is inoperative, the pneumatic control will operate and the brake pipe pressure be reduced at the desired fixed rate by means of the brake valve. The brake pipe reduction is limited to a predetermined amount, the same as in electric service. If any of the service application magnets in the train are inoperative, for any reason, thus causing the brake pipe reduction made by the magnet valves to be less rapid than the reduction of the equalizing reservoir, through the preliminary exhaust port of the brake valve the equalizing piston will lift, open the equalizing discharge valve, and bring the rate of reduction up to the required point. This feature may also be a telltale, and should warn the motorman of any inoperative service application magnets.

REDUCTION LIMITING FEATURE.

The reduction limiting valve, as it is called, is composed of a piston and slide valve, the back of piston and slide-valve chamber being always connected to the equalizing reservoir, and the face always connected to the reduction limiting reservoir.

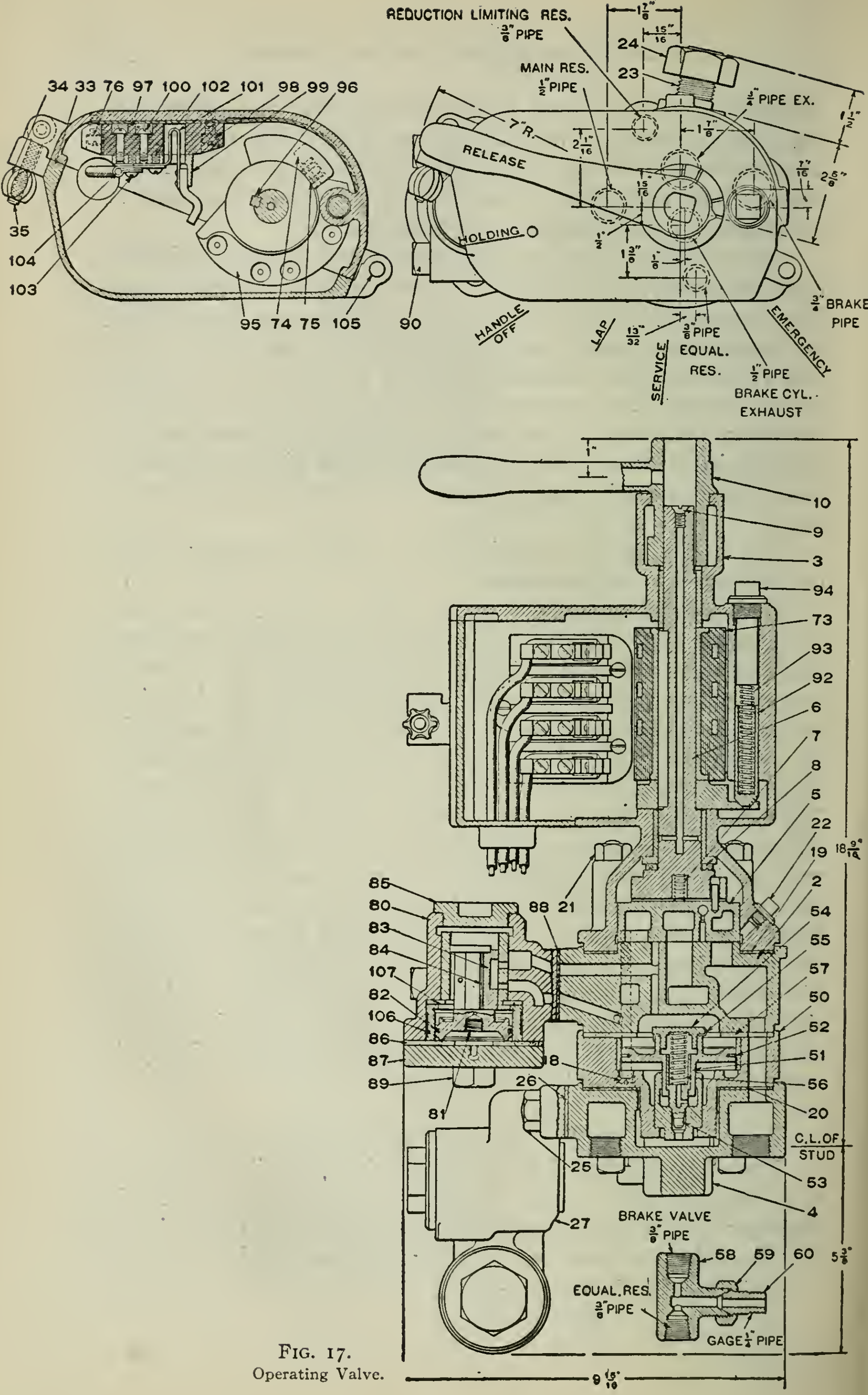


FIG. 17.
Operating Valve.

Normally, the limiting reservoir is connected to the atmosphere, but in service position, while the equalizing reservoir is being reduced through the preliminary exhaust port, the reduction limiting reservoir is being charged. When these pressures are nearly equal, the piston and slide valve will move and cut off communication between the preliminary exhaust and the atmosphere, and, since the equalizing reservoir and direct exhaust ports pass through this slide-valve cavity to the atmosphere, no further reduction can occur through this source; consequently, when the brake pipe pressure has been reduced to the equalizing reservoir pressure, the equalizing discharge valve will seat, thus limiting the brake pipe reduction. No further reduction can now be made unless the brake-valve handle is moved to emergency position. The size of the preliminary exhaust and that of the limiting reservoir charging ports are such that the equalizing and limiting reservoir pressures will be equal at about 50#.

NON-OVERCHARGE OF EQUALIZING RESERVOIR.

The improved design of equalizing discharge valve piston (collapsible type) prevents the overcharge of the equalizing reservoir. Since the equalizing reservoir pressure is on the top of the equalizing piston, and the brake-pipe pressure underneath, if the equalizing reservoir charges faster than the brake pipe a differential will be built up on the upper side of this piston, which will then collapse, allowing pressure in the equalizing reservoir to equalize into the brake pipe through grooves in the piston bush. The spring in this piston will yield with a differential of about 2#.

DIRECT EXHAUST FEATURE.

In service position there is a direct exhaust port leading from the brake pipe to the atmosphere. This insures an immediate reduction of brake-pipe pressure, and eliminates the time element inherent in previous designs of equalizing discharge valve type of brake valves.

In release position of the brake valve, the brake pipe charging port and the equalizing reservoir charging port are open, thus charging the brake pipe and equalizing reservoir to feed-valve pressure. The reduction limiting reservoir port and the brake cylinder port are open to the atmosphere.

In this position of the brake valve there is no electrical connection made; therefore, the release magnet valve is held open and the emergency and service magnet valves are held closed by their respective springs.

In holding position all port connections are the same as in release, except that the brake-cylinder port is closed. The brake-pipe charging port being open, permits the recharge of the brake pipe and the release of all the brakes in the train but on the head car. Thus the brake on this leading car may be retained, or, if desired, graduated off by moving brake-valve handle between release and holding positions.

As in release, there are no electrical connections made in this position.

In service position the preliminary exhaust port is open, thus reducing the equalizing reservoir pressure *via* the limiting slide-valve exhaust cavity. The reduction limiting reservoir charging port is open, thus charging this reservoir as the equalizing reservoir is being reduced. The equalizing discharge port is open, as is also the direct exhaust port.

In this position of the brake valve the release magnet line remains connected to the supply, and, in addition, the service magnet line is connected, and thus the release and service magnets are energized and release magnet valve is held closed and service magnet valve open.

The handle-off position, as its name implies, is the position of the valve which permits the removal of the handle.

In former designs of pneumatic brake valves the handle is removed in *lap position.*

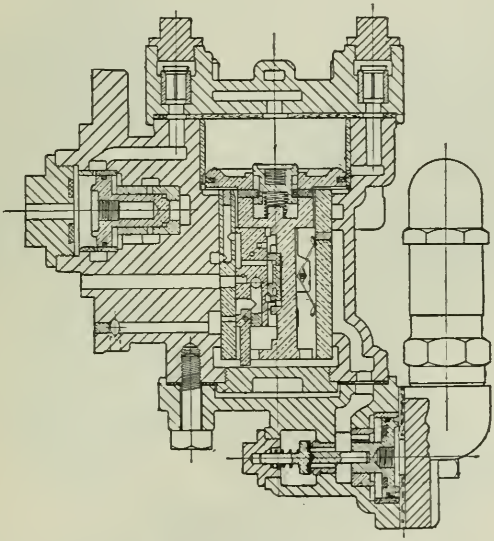
To permit of the elimination of the brake-pipe cut-out cock, if so desired, the brake-pipe exhaust from the equalizing discharge valve is carried up through the rotary valve and is open in lap position. It will then be evident that this position, *i.e., handle-off,* in which the equalizing discharge is closed, is necessary.

In lap position all ports are closed except the equalizing discharge valve ports; the necessity for this being open is evident, since the brake-pipe exhaust from the equalizing discharge valve must remain open until the brake-pipe pressure has been drawn down equal to the reduction made in the equalizing reservoir pressure.

In emergency position the brake pipe is connected direct to the atmosphere through a large port, and the emergency magnet line is connected to the supply, thus energizing emergency magnet and opening emergency magnet valve.

The triple valve, which forms a part of this equipment, comprises three main portions, bolted to a suspension bracket (or to a pipe bracket, which, in turn, is bolted to the brake-cylinder pressure head).

FIG. 18.

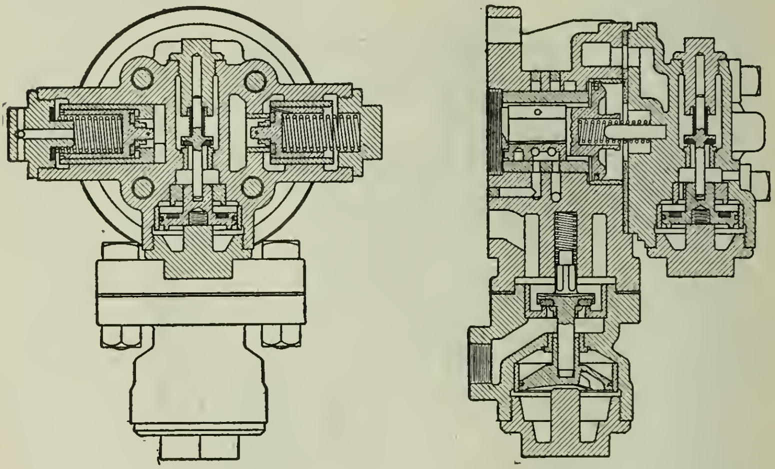


Equalizing Portion.

Fig. 18 shows the *equalizing portion,* in which are: The equalizing piston (with reduction limiting valve); equalizing slide valve and graduating valve, which directly control the pneumatic service application and indirectly the release of the brakes, and the charging of the auxiliary and supplementary reservoirs; the supplementary reservoir check valve, which separates this reservoir from the auxiliary reservoir when a brake-pipe reduction is made; the service port check valve, which prevents back flow of brake-cylinder pressure to the face of the release piston when releasing the brake; the release piston, which directly controls the release of the brakes; the safety valve, which blows down the auxiliary reservoir pressure in an emergency application; the cut-off piston and valve, which prevent main reservoir air from flowing to the safety valve and to the auxiliary reservoir during an emergency application; the direct and graduated release cylinder cap, which is to be placed in one position or the other, according as a graduated release of the brake is or is not to be provided for.

Fig. 19 shows the *emergency portion,* in which are: The quick-action piston and valve, by means of which brake-pipe air is vented to atmosphere in emergency; the pilot valve, which vents air from the back of emergency valve in emergency application; the emergency valve, which, when open, admits main reservoir air direct to the brake cylinder; the emergency slide-valve piston and slide valve, which control the charging of the quick-action chamber and the quick-action closing chamber, the flow of air from the quick-action chamber to the cut-off valve piston, the flow of air from the quick-action closing chamber to the quick-action piston and emergency switch piston, the flow of air to the face of pilot-valve piston, venting of air from the face of cut-off valve piston and opening of the quick-action chamber maintaining port; the protection valve, which auto-

FIG. 19.

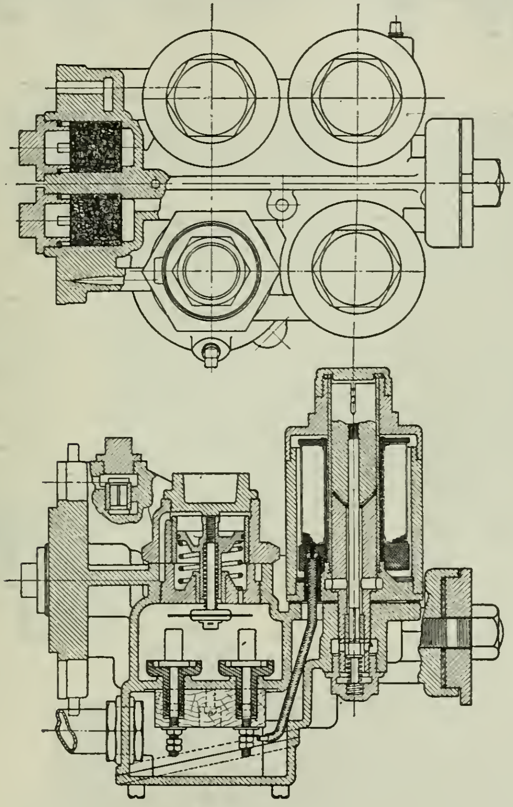


Emergency Portion.

matically produces quick action when the brake-pipe pressure is reduced to a predetermined value.

Fig. 20 shows the *magnet bracket portion,* in which are: The emergency switch, which is closed at the same time the quick-action valve is opened (by air from the quick-action closing chamber); the service application magnet and valve, by means of which the service brake-pipe reduction is made at each car; the release magnet and valve, which control the electric release of the brake; the emergency magnet valve, which causes the quick-action parts to operate by venting air from the face of the emergency slide-valve piston to atmosphere; the magnet valve cut-out cap, by means of which either or both of the application magnets may be cut out or cut in.

FIG. 20.



Magnet Bracket.

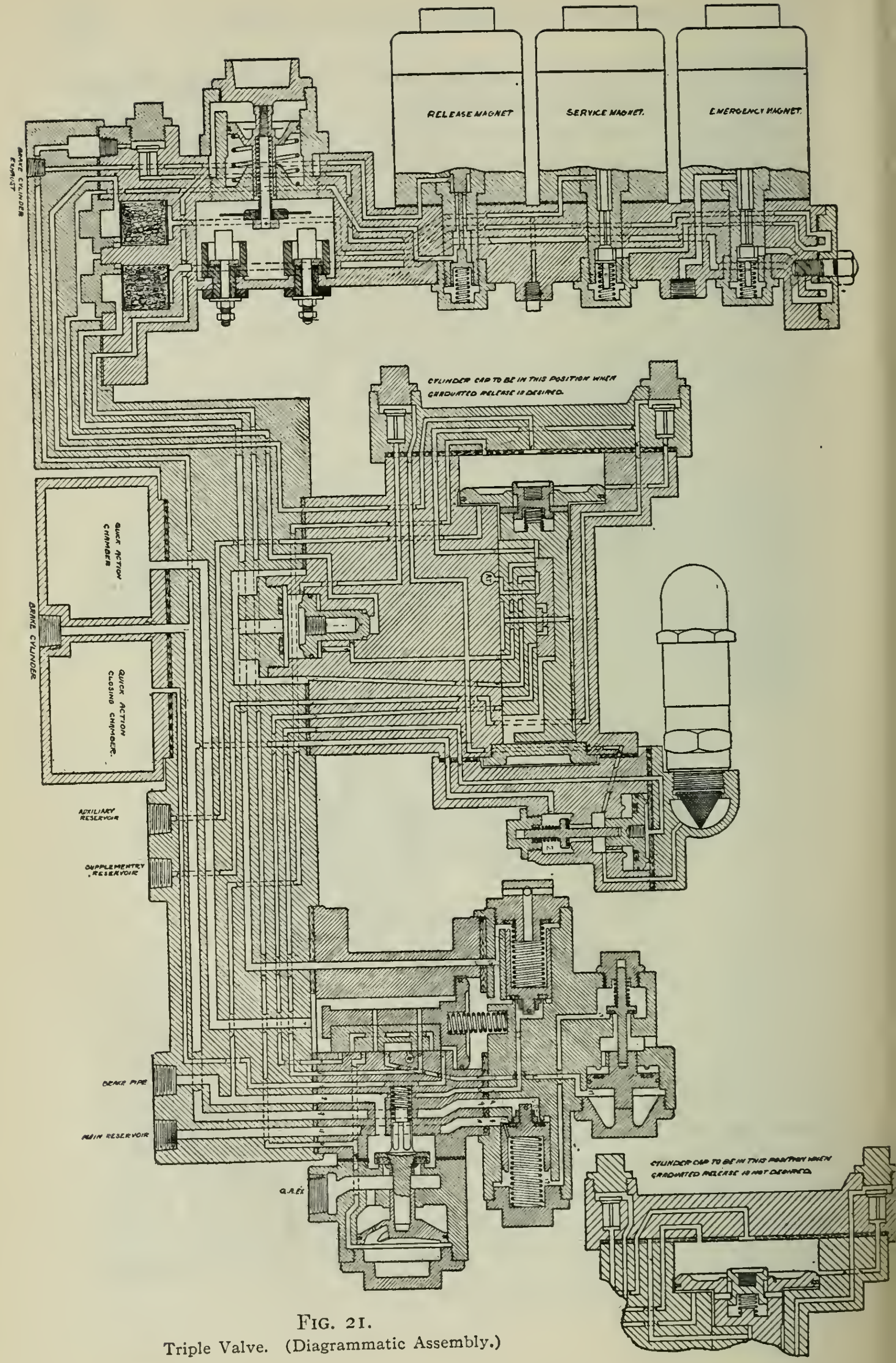


FIG. 21.
Triple Valve. (Diagrammatic Assembly.)

OPERATION OF EQUIPMENT.

Charging Position.

Fig. 21 shows the triple valve diagrammatically. Air from the brake pipe enters as indicated, and flows to the face of the equalizing piston, moving it to release position, thence through the feed groove to the slide-valve chamber and to auxiliary reservoir, and past supplementary reservoir check valve, thence to supplementary reservoir and to auxiliary reservoir, through equalizing slide valve. The auxiliary reservoir is thus charged from two sources. Brake-pipe air also flows to the underside of the quick-action valve. Air from the brake pipe also acts directly on the lower seat of the protection valve, which will remain seated downward until a certain predetermined pressure is reached (governed by protection-valve spring), when it will move very quickly to its closed position, owing to its differential areas, and to the fact that the space at the back of the protection valve is always open to the atmosphere.

With the protection valve closed, the brake-pipe air will flow past this valve to the face of the emergency slide-valve piston, forcing the latter to its release position (if not already there), and charging the quick-action and the quick-action closing chambers through the feed groove around the emergency piston.

The brake pipe is also in communication with the emergency application magnet valve by way of the protection valve and through the strainer and the magnet valve cut-out cap (the latter being in its normal position).

The chamber on the face of the equalizing piston is in communication with the service application magnet valve by way of the strainer and magnet-valve cut-out cap.

ELECTRIC SERVICE APPLICATION.

When the brake-valve handle is moved to application position, the lap position of the valve is passed over, in which position the release magnet circuit is closed, thus energizing this magnet and seating the release magnet valve, which is held closed in service position also. The service application magnet circuit is closed at this time, energizing this magnet, which, in turn, opens the service application magnet valve. This allows air from the brake pipe to flow past the brake-cylinder check valve to the brake cylinder (or directly to the atmosphere, if desired). The electric service application port is choked down to the proper size to permit of a rate of brake-pipe reduction which will cause the equalizing piston, graduating valve, and equalizing slide valve to move over to service position; but this rate of reduction is not rapid enough to move the emergency piston and slide valve, since, under these conditions, the quick-action chamber pressure can reduce through its feed groove as rapidly as the brake-pipe pressure is being reduced. This insures the desired service application and prevents the possibility of undesired quick action.

The first movement of the equalizing piston and graduating valve toward service position closes the graduated release port, and opens the service port through the slide valve, which, however, has not yet moved, so as to open this port to the brake cylinder.

The first movement of the equalizing piston and graduating valve also connects, through cavity in graduating valve, the port which leads to the face of the large end of release piston, with port leading to the back of this piston, thus balancing these pressures, and, since the small end of this piston is connected to the atmosphere, it will be forced to its closed position, due to the differential areas.

Also, this first movement of the piston and graduating valve opens the resistance-increasing cavity in the face of the equalizing slide valve to atmospheric pressure. This increase in the amount of the under surface of the slide valve, which is exposed to the atmosphere, increases the resistance which has to be overcome before the equalizing slide valve can be moved. The object of this is two-fold: First, to reduce the sensitiveness of the valve sufficiently to prevent fluctuations in brake-pipe pressure, due to the feed valve or other causes, from producing undesired light-service applications or brakes creeping on; second, to insure the making of such a brake-pipe reduction in applying the brakes that no trouble in releasing can result from inability to establish sufficient differential, as may be the case where the brakes will apply on a very light brake-pipe reduction.

It will be noted that the first movement of the equalizing piston in returning toward release position disconnects the resistance-increasing cavity from the atmosphere and re-establishes its communication to the auxiliary reservoir, so that the added resistance to motion is at once eliminated, and the valve will consequently be easier to release than to apply.

When sufficient differential has been established to cause the equalizing piston to move the slide valve to its service position, the opening of the service port permits air to flow from the auxiliary reservoir past the graduating valve, and through the slide valve to the brake cylinder by way of the release piston, service port check valve, and cut-off valve. The brake-cylinder pressure will continue to be increased in this manner until it equalizes with the auxiliary reservoir, or (in case a full service reduction in brake-pipe pressure is not made) until the auxiliary reservoir pressure is reduced to a point slightly lower than the pressure in the brake pipe. In the latter case, the equalizing piston and graduating valve will move back until the piston stops against the slide valve in service lap position, which closes the service port and prevents a further building up of brake-cylinder pressure, and opens the resistance-increasing port to auxiliary reservoir pressure, thus again balancing the slide valve and rendering it more sensitive to release than it was to apply.

The service application magnet may be held energized, thus holding the service application magnet valve open and causing a continuous brake-pipe reduction, which permits the auxiliary and brake-cylinder pressure to equalize (giving a full service application of the brakes), or it may be energized for shorter periods of time, thus causing partial brake applications to any desired degree, after which the parts will move to service lap position, as above mentioned. This energizing of service application magnet may be repeated as many times as desired, each time causing an increase in brake-cylinder pressure, corresponding to the amount of brake-pipe reduction, until equalization takes place.

REDUCTION LIMITING FEATURE IN THE EQUALIZING PISTON.

Ordinarily, the service magnet makes a brake-pipe reduction by connecting the brake pipe to the brake cylinder; this then means that these two pressures are approaching each other, and as they near the equalizing pressure the rate of reduction in the brake pipe is gradually decreasing to zero.

In order to procure the desired pressure in the given time, then, the rate of reduction at first is quite rapid and the margin between it and the emergency rate is very small, and this margin is broadened as equalization is approached.

For those who may desire to have a uniform margin between the service and emergency rates of reduction, provision has been made to close the service magnet connection to the service brake cylinder and open same to the atmosphere. Then, in order to limit the brake-pipe reduction to the equalization point, the reduction limiting check valve is embodied in the equalizing piston.

When the service magnet valve is open, and the equalizing piston is moved over toward service position, the reduction in auxiliary reservoir pressure which follows the opening of the service port stops the movement of the equalizing parts before the reduction limiting check valve seats against the cylinder cap gasket.

If a continuous brake-pipe reduction is made, the equalizing parts will remain in this position until the auxiliary reservoir and brake-cylinder pressures have equalized; then a further reduction in brake-pipe pressure will cause these parts to be moved by the higher auxiliary reservoir pressure, until the reduction limiting valve seals against the cylinder cap gasket, thus preventing an over-reduction in brake-pipe pressure.

ELECTRIC EMERGENCY APPLICATION.

With the brake-valve handle in emergency position, the emergency application magnet circuit is closed, energizing this magnet, which, in turn, opens the emergency application magnet valve and allows air from the brake pipe to flow to the atmosphere. This opening through the emergency application magnet valve to the atmosphere is of such size as to permit of a rate of brake-pipe reduction which will cause the emergency slide-valve piston and its slide valve to move to emergency position, and also the equalizing piston, graduating and equalizing slide valves to move over until the piston rests against the cylinder cap gasket.

With the equalizing piston, graduating valve, and slide valve in emergency position, the auxiliary reservoir is connected to the safety valve the same as in service operation. Consequently, the pressure in this reservoir will be reduced by the safety valve to the point at which it closes. This reduction of auxiliary reservoir pressure in emergency insures that the brake will be easily released thereafter.

With emergency slide valve in emergency position, air flows through the slide valve from quick-action closing chamber to the quick-action piston, thus forcing the quick-action valve open, thereby venting brake-pipe air to the atmosphere (which causes a sudden local brake-pipe reduction that starts pneumatic quick action); and to the emergency switch piston, thereby closing the emergency switch, which serves as a circuit-closer to cause simultaneous quick action throughout the train when originating pneumatically.

The quick-action valve will remain open and emergency switch closed until the quick-action closing chamber drains by way of the quick-action exhaust to the atmosphere through small drilled port in quick-action piston.

Also, in this position of the emergency slide valve, the port leading to the face of the cut-off piston is connected to the atmosphere through the cavity in the slide valve; thus cut-off valve will be closed by its spring.

Air also flows from the quick-action chamber through the emergency slide valve to the face of the pilot-valve piston, thus opening the pilot valve and venting air from the back of the emergency valve to the atmosphere. Since main reservoir pressure is exerted on the face of the emergency valve, this valve will be then forced open very quickly, allowing main reservoir air to flow direct to the brake cylinder; the cut-off valve, being closed, prevents main reservoir air flowing to the safety valve or to the auxiliary reservoir, thus giving full main reservoir pressure in the brake cylinder.

A connection is also made in this position from the quick-action chamber to the auxiliary reservoir. Then the air in the auxiliary reservoir is made to maintain the quick-action chamber pressure (since its volume is quite small) against possible leakage past the pilot-valve piston, thus insuring that the pilot valve will remain open, thereby maintaining the high-brake cylinder pressure in emergency.

ELECTRIC RELEASE AFTER SERVICE APPLICATION.

When it is desired to release the brake, the brake-valve handle is moved to release position, in which the release magnet circuit is open, and this magnet is de-energized, allowing the release magnet valve to be opened by its spring. The brake-pipe charging port in the brake valve is also open, restoring the air in the brake pipe to its initial pressure. This increase in the brake-pipe pressure forces the equalizing piston, graduating and equalizing slide valves to release position in which the brake-cylinder air is exhausted to the atmosphere, by way of the cut-off valve, release piston, and release magnet valve. If the brake valve is allowed to remain in this position, the brake-cylinder air will be exhausted in the shortest possible time.

ELECTRIC RELEASE AFTER EMERGENCY APPLICATION.

After an emergency application has been made, the quick-action valve will remain open and the emergency switch closed until the quick-action closing chamber air has drained to the atmosphere through the small drilled port in quick-action piston, after which the quick-action valve will be closed and the emergency switch opened by their respective springs.

With the quick-action valve closed and the brake-pipe pressure being restored, the protection valve will be the first to go to its normal (release) position, which will, in turn, admit air to the face of emergency slide-valve piston, forcing it to release position and charging quick-action and quick-action closing chambers, as described under "Charging." Brake-pipe pressure has also been built up on the face of equalizing piston, forcing it, with its valves, to release position. With emergency slide valve in release position, the chamber on the face of the pilot-valve piston is connected to the atmosphere. The pilot valve will then be closed by its spring. The emergency valve will remain open until the pressures on the front and back of this valve have equalized through the small drilled port, when it will be closed by its spring. Quick-action chamber air also flows to the face of the cut-off valve piston, thereby opening the cut-off valve and allowing the exhaust of the high-pressure cylinder air past the cut-off valve, small end of the release piston, and the release magnet valve.

GRADUATED RELEASE.

The release of the brake may be graduated by moving the brake-valve handle between release and lap positions. The brake-pipe charging port of the brake valve is open in release position;

therefore, the equalizing parts of the triple valve will be moved to release position. In this position the cavity in the graduating valve connects to the atmosphere the port leading to the face of the large end of the release piston, which will then be forced open, due to the brake-cylinder pressure on the back. In release position of the brake valve the release magnet circuit is open; this magnet is then de-energized and release magnet valve is then held open by its spring. Brake-cylinder air can then flow to atmosphere past the cut-off valve, small end of release piston and release magnet valve; but when the equalizing slide valve is in release position and the graduated release cylinder cap in the position marked "graduated release," the graduated release port is open, which connects the supplementary and auxiliary reservoirs. This former volume was not used in service operation and will still have its initial pressure. The supplementary reservoir air flowing back into the auxiliary reservoir will quickly raise the pressure in the latter to a point which is slightly in excess of that in the brake pipe, and, consequently, the equalizing piston and graduating valve will be moved to graduated release lap position, in which the graduated release port is closed. But the cavity in the graduating valve connects the ports leading to the back and to the face of the large end of release piston, thus balancing these pressures. This piston will then be forced to closed position, due to the differential areas, cutting off the release of brake-cylinder pressure. No further reduction of brake-cylinder pressure can now be made until the brake-pipe pressure is again increased and equalizing piston and graduating valve moved back to release position.

Even with the direct and graduated release cap in "direct release" position, which closes the supplementary reservoir connection to the auxiliary reservoir, it is always possible (when the electric features are operative) to graduate the release of the brake by means of the release magnet valve alone, if the brake-valve handle is moved between release and lap positions.

PNEUMATIC OPERATION.

In case any of the electric features should be inoperative, through loss of current or other causes, the equipment may be operated as any of the older types, the brake-pipe reductions then being made by means of the brake valve alone (the positions of the brake-valve handle being the same for both electric and pneumatic operation).

PNEUMATIC SERVICE APPLICATION.

With the brake-valve handle in service position, the preliminary exhaust port in the brake valve is opened, allowing equalizing piston to lift and produce a rate of brake-pipe reduction sufficiently rapid to move the equalizing piston, graduating and slide valves to service position. The rate of reduction as fixed by the brake valve is, however, not as rapid as that at which the quick-action chamber pressures can be reduced through its feed groove into the brake pipe, thus positively guarding against undesired quick action.

The flow of auxiliary air into the brake cylinder is the same in pneumatic as in electrical service operation.

PNEUMATIC EMERGENCY APPLICATION.

With brake-valve handle in this position, the emergency exhaust port is open and permits of such a rapid rate of brake-pipe reduction that the quick-action chamber pressure cannot reduce as rapidly through its feed groove as the brake-pipe pressure is being reduced through the brake valve. Consequently, the emergency piston and its slide valve are moved to their emergency positions. The equalizing piston has also moved (carrying with it the slide valve and graduating valve) against the cylinder cap gasket.

The operation of the various valves is now the same as previously described under " Electric Emergency Application."

PNEUMATIC GRADUATED RELEASE.

This is accomplished in the same manner as previously described, except that the release magnet valve is open at all times. and the graduated release controlled entirely by the release piston.

PROTECTION FEATURE.

In case there is excessive leakage, after a full service application has been made, which will reduce the brake-pipe pressure to a certain predetermined point, the protection valve will be forced open by its spring, thus connecting the face of the emergency slide-valve piston to the atmosphere, past the protection valve seat, and producing a rate of brake-pipe reduction that will cause emergency piston and slide valve to move to emergency position, thus causing quick action as previously described.

(*To be continued*)

Synthetic Rubber, by the Production and Polymerization of Butadiene, Isoprene, and Their Homologues. W. H. PERKIN, JR., F.R.S. (*Jour. Soc. Chem. Ind.*, xxxi, No. 13, 616.)—This article is exceedingly interesting and contains the history of the production of synthetic rubber. A concise summary follows. There can be no doubt that rubber may be obtained synthetically by the polymerization of isoprene and its homologues, and that the synthetic product is really rubber and strictly comparable to natural rubbers. These facts have been confirmed by a large number of chemists working independently. There is no doubt that Tilden prepared specimens of crude synthetic rubber in 1882 and 1884, long previous to those produced in 1909 by Bayer & Co., of Elberfeld, which have been claimed as the first true samples of synthetic rubber. Greville Williams was the first to isolate isoprene from the products of the destructive distillation of rubber in a fairly pure state, and was the first to observe the transformation of this hydrocarbon into a rubber-like body. This was in 1860. It is clear that he considered that both caoutchouc and gutta-percha are polymers of isoprene. The article then gives a detailed account of several methods of obtaining rubber synthetically, which are: firstly, the preparation of isoprene from *iso*amylalcohol and its subsequent polymerization (this process depends for its success on the discovery of some cheap method of obtaining *iso*amylalcohol in quantity); secondly, the conversion of butyl alcohol, obtained cheaply and in any quantity by Professor Fernback's new method of fermentation, into butadiene; and, thirdly, the conversion of aldehyde through aldol into butadiene, the butadiene being then, in each case, polymerized to butadiene rubber by Dr. Mathews's sodium polymerization process.

National Association of Cotton Manufacturers.—The 93rd Semi-Annual Meeting will be held at The Griswold, near New London, Conn., on September 9th, 10th, and 11th. The following are among the subjects which will be discussed at the meeting: Cotton Growing in India; Economic Use of Lubricating Oils; Lithographic Method of Printing Cotton; Raising Cotton in California; Spinning Value of Different Grades of Cotton; Tape Driving for Spindles; Wastes in Cotton Manufacture. A full programme will be issued shortly before the meeting.

Groups of Electrons in a Sphere of Positive Electricity. A. E. HAAS. (*Akad. Wiss. Wien. Ber.*, cxx, 2a, 1111.)—In Thomson's electronic model of an atom it is a necessary condition of equilibrium that the central attraction on any electron shall be equal to the resultant repulsions of the other electrons and shall also be in the same direction. This condition is not fulfilled in an outer ring of 11, and an inner ring of 7 electrons, and one electron at the centre of the sphere of positive electricity. This work is a mathematical search for stable groups fulfilling the condition of equilibrium stated above. The types considered comprise similar and concentric regular polygons, double pyramids, prisms, and concentric regular polyhedra. An interesting result is reached concerning the maximum number of electrons capable of forming a ring in equilibrium, but not necessarily stable. It proves to be 471, as against Thomson's maximum of 5 for stable equilibrium; 471 is just double the atomic weight of uranium. Another result is that when there is equilibrium in a state of rest, and rotation supervenes, the new configuration of equilibrium is geometrically similar, but all the linear dimensions are increased in the same ratio.

Formation and Velocity of Negative Ions in Canal Rays. J. KOENIGSBERGER and J. KUTSCHEWSKI. (*Deutsch. Phys. Gesell. Verh.*, xiv, 1, 1.)—Many observers are of opinion that the negative ions in oxygen are due to the presence of water vapor in the discharge tube, and possibly of other compounds containing oxygen. The same explanation serves for the negative ions in hydrogen. It is now found that all canal-ray ions are originally positive, irrespective of whether they become positive or negative later. The velocity of the negative portion is always smaller than that of the positive. The formation of the negative ions is caused at the seat of ionization more particularly by rays of smaller velocity.

Use of Manganese in Nickel Alloys. ANON. (*Brass World*, viii, 6, 191.)—Manganese is known as a good deoxidizer of these alloys. It is usually added alone, which is not a good method because it melts at about the same temperature as steel, which is much higher than the melting point of nickel alloys. It is true that it will melt in these alloys if given sufficient time, but as a rule the time allowed is much too short and the bulk of the manganese is removed with the skimmings. The proper way to add it is to make a rich copper manganese alloy, containing 70 per cent. copper and 30 per cent. manganese, by melting the two together, stirring them and pouring out into small bars. This alloy, called manganese copper or cupro-manganese, is added to the metal or alloy in the proportion of about 5 ounces to 100 pounds of the molten metal. It is introduced after the metal has melted, and not allowed to melt with the other metals.

NOTES FROM THE BUREAU OF STANDARDS.

SELECTIVE RADIATION FROM VARIOUS SUBSTANCES.

BY

W. W. Coblentz.

THE present paper contains further contributions to the study of the radiating properties of various substances (see Nos. 91, 97, 131, 156). This includes a determination of (I) the radiation constants of platinum (see No. 105), (II) the emission spectrum of neon, helium, and mercury, (III) the emissivity of different parts of the acetylene flame, (IV) the variation of emissivity with thickness of the radiating layer, oxides, (V) the radiation from a uniformly heated cavity and from its enclosing walls, (VI) standard spectral energy curves, and, (Note I) light filters which absorb all the infra-red (see No. 168).

The spectral energy curves of these sources of radiation were examined by means of a vacuum bolometer, mirror spectrometer, and fluorite prism.

The radiation constants of platinum were obtained from spectral energy curves, the temperatures being measured by means of an optical pyrometer and also by means of a fine wire thermocouple. The two methods of temperature measurement give concordant results, which confirm the previous conclusions that the radiation constants are complex functions of the temperature.

The high radiant efficiency of vacuum tubes is owing to the small amount of infra-red radiation that is emitted. Neon is unique in having the maximum emission in the visible (red) part of the spectrum. This explains the low energy input (high efficiency) required to excite this gas to light emission. In the helium and in the quartz mercury lamps there are intense infra-red emission lines which lower the radiant efficiency. In the mercury vapor lamp it was found that the infra-red and the yellow lines increase in the same proportion with increase in energy input; but the intense green line does not increase at the same rate in intensity, although it is the most easily excited to light emission. Hence, after exceeding a given energy input, there is a decrease in the radiant efficiency. For the intensity of the yellow line, increasing as it does in the same proportion as the infra-red, is not sufficient to counterbalance the loss by radiation in the infra-red, and the result is a decrease in the ratio of the luminous to the total radiation emitted.

THE STANDARDIZATION OF POTASSIUM PERMANGANATE SOLUTION BY SODIUM OXALATE.[1]

BY
R. S. McBride,
Assistant Chemist.

It was desired to determine the effect of the variation of the following factors upon the result obtained in the standardization of potassium permanganate by sodium oxalate, viz.: temperature, acidity, volume of solution, rate of addition of the permanganate, access of air, presence of added manganous sulphate, and, in connection with these, the corrections necessary upon the apparent end-points. In order to accomplish such determination the factors were varied one at a time, noting the effect, if any, produced upon the apparent value of the permanganate. Each of the factors was found to have a definite, though small, influence upon the result.

The effects were undoubtedly due to a variation of the reaction from the normal course as usually given. Such variations might tend to cause the use of an excess of either permanganate or oxalate; or both sorts of influence might operate at the same time, in equal or unequal degree. The nine possible sources of variation are: (*a*) loss of oxalic acid by volatilization, (*b*) decomposition of oxalic acid by water, (*c*) decomposition of oxalic acid by sulphuric acid, (*d*) oxidation of oxalic acid by the air, (*e*) incomplete oxidation of the oxalic acid, (*f*) liberation of oxygen during the reaction, (*g*) incomplete reduction of the permanganate to the manganous state, (*h*) presence of impurities in the oxalate of either greater or less reducing power, and (*i*) formation of other products of the oxidation than carbon dioxide and water. Of these, only two appeared to be at all probable, viz., loss of oxygen and atmospheric oxidation of the oxalic acid; and, furthermore, only the first of these two could be held in the light of all of the experiments reported.

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[1] Abstract, Bulletin of the Bureau of Standards, vol. 8.

If the main source of error is due to an oxygen loss, the higher values obtained in the various series must be taken as correct. On this basis the following method of titration is recommended: in a 400 c.c. beaker dissolve 0.25–0.3 g. of sodium oxalate in 200 to 250 c.c. of hot water (80–90°) and add 10 c.c. of 1 : 1 sulphuric acid. Titrate at once with N/10 $KMnO_4$ solution, *stirring the liquid vigorously and continuously*. . The permanganate must not be added more rapidly than 10–15 c.c. per minute, and the last ½ to 1 c.c. must be added dropwise, with particular care to allow each drop to be wholly decolorized before the next is added. The solution should not be below 60° by the time the end-point is reached. The excess of permanganate used to cause the end-point color must be estimated by matching the color in another beaker containing the same bulk of acid and hot water.

Under the above condition the agreement of duplicates should be at least 1 part in 2000; and the variation from absolute accuracy of average values is probably not greater than 0.05 per cent. Under other conditions than those described it is possible to obtain correct results; but, using the procedure recommended, the difficulties of the titration are reduced to a minimum.

"ELECTRIC WIRE AND CABLE TERMINOLOGY."[1]

ON account of the growing need for precise definitions in the field of conductor terminology, the Standards Committee of the American Institute of Electrical Engineers requested the Bureau of Standards to prepare a circular on the subject. As a result of extensive correspondence and consultation it was found possible to formulate a reasonably consistent body of definitions without introducing radical departures from existing general practice. Seventeen of the most important terms have been defined.

It was found necessary to give the most care and thought to the terms "strand" and "cable." In the strong preponderance of current opinion, "strand" implies a component part of a cable or stranded conductor, each part being either a combination of wires or a single wire. It fortunately happens that this is precisely in accord with the non-technical meaning of "strand." A "cable" is defined as either (1) a stranded conductor, *i.e.*, a conductor composed of a group of wires, or (2) a combination of conductors insulated from one another. The first kind of cable may be either bare or insulated. The component conductors of the second kind of cable may be either solid or stranded, and the whole may or may not have a common insulating covering.

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[1] Abstract, Circular of the Bureau of Standards, No. 37, 1912.

From the main terms defined, the minor terms should follow logically, and most or all of the confusion which has existed on this subject should disappear.

Pottery Found by Excavation at Susa. A. GRANGER. (*Comptes Rend.*, cliv, 1162.)—The Morgan mission deposited ware and fragments at the Louvre which belong to what are termed "the first and second periods," the earlier being superior in execution and finish. Some pieces were hand worked and the rest turned. Ware of the same epoch showed evidences of great difference in the skill of the makers. The local clay is a ferruginous marl of the composition:—clay 28.57, sand 27.10, chalk 37.58, combined water 4.05, and moisture 2.70 per cent. It melts to a brown glass at 1400° C. The pottery was fired at less than 1000° C. Kilns were found, but in such ruinous condition that it was impossible to reconstruct them. The stains used in the ware were iron and a little manganese, probably found as a natural manganiferous iron oxide. In the "first period" the stain was fired with a flux, in the "second period" it was simply brushed on and not fired.

The Disappearance of Higher Boiling Phenols in Creosoted Wood. S. CABOT. (*J. Ind. Eng. Chem.*, iv, 266.)—The higher-boiling coal-tar phenols on prolonged exposure to air become converted into tarry substances insoluble in benzene but soluble in acetone. A portion of this tarry matter is insoluble in 10 per cent. sodium hydroxide solution, but soluble as an alkali salt in water, a portion forms a salt with alkali that undergoes hydrolysis on solution; and a third portion has a very slight affinity for alkali. The higher-boiling phenols remain in creosoted wood in the form of complex oxidation products.

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Ohio University, Bulletin, April, 1912. Athens, Ohio, 1912. (From the University.)

Wellesley College, Bulletin, January, 1912. Wellesley, Mass., 1912. (From the University.)

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Yale University, President's Report, 1911–1912. New Haven, Conn., 1912. (From the University.)

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U. S. Department of Commerce and Labor, Imported Merchandise Entered for Consumption in the United States, and Duties Collected Thereon, March, 1912. Washington, D. C., 1912. (From the Department.)

Clark University, Register and Twenty-fourth Official Announcement, 1912. Worcester, Mass., 1912. (From the Department.)

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Lectures delivered at the Centenary Celebration of the First Commercial Gas Company to Sell Gas as an Illuminant, held at the Franklin Institute, Philadelphia, Pa., April 18 and 19, 1912. Edited and published by the American Gas Institute. 174 pages, illustrations, 8vo. New York, no date.

Analysis of Metallurgical and Engineering Materials. A systematic arrangement of laboratory methods by Henry Wysor, B.S. 82 pages, illustrations, quarto. Easton, Pa., Chemical Publishing Company, 1912.

The Half-Tone Process, a practical manual of photo-engraving in half-tone on zinc, copper, and brass, with chapters on three-color work and photo-lithography for offset printing by Julius Verfasser. Fifth edition, fully revised. 378 pages, illustrations, plates, colored frontispiece, 8vo. London, Iliffe & Sons, Ltd., no date. Price, 7 shillings 6 pence.

U. S. Department of Agriculture: Forest Service.—Forest Products Laboratory Series, Experiments with jack pine and hemlock for mechanical pulp by J. H. Thickens. 29 pages, illustrations, plates and samples of paper, 8vo. Office of Public Roads, Bulletin No. 44—The physical testing of rock for road building, including the methods used and the results obtained, by Albert T. Goldbeck and Frank H. Jackson, Jr. 96 pages, illustrations, 8vo. Bulletin No. 46—Oil-mixed Portland cement concrete, by Logan Waller Page. 28 pages, illustrations, plates, 8vo. Washington, Government Printing Office, 1912.

U. S. Bureau of Mines: Bulletin No. 18—The transmission of heat into steam boilers, by Henry Kreisinger and Walter T. Ray. 180 pages, illustrations, plates, 8vo. Technical Paper No. 17—The effect of stemming on the efficiency of explosives, by Walter O. Snelling and Clarence Hall. 20 pages, illustrations, 8vo. Technical Paper No. 18—Magazines and thaw houses for explosives, by Clarence Hall and Spencer P. Howell. 34 pages, illustrations, plates, 8vo. Technical Paper No. 23—Ignition of gas by miniature electric lamps with tungsten filaments, by H. H. Clark. Washington, Government Printing Office, 1912.

Providence, R. I., City Engineer. Annual report for the year 1911. 86 pages, plates, tables, maps, 8vo. Providence, City Printers, 1912.

Canada, Department of Mines, Mines Branch: Mica: its occurrence, exploitation, and uses. Second edition, by Hugh S. de Schmid, M.E. 411 pages, illustrations, plates, maps, 8vo. Bulletin No. 6—Diamond drilling at Point Mamainse, Province of Ontario, by Alfred C. Lane, Ph.D.; introductory by Alfred W. G. Wilson, Ph.D. 59 pages, illustrations, 8vo. Ottawa, Government Printing Bureau, 1912.

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North Carolina Geological and Economic Survey: Economic Paper No. 25—Proceedings of second annual convention of the North Carolina Forestry Association, held at Raleigh, N. C., February 21, 1912. Compiled by J. S. Holmes, Forester. Forest fires in North Carolina during 1911, by J. S. Holmes. Suggested forestry legislation. 66 pages, 8vo. Economic Paper No. 26—Proceedings of Fourth Annual Drainage Convention, held at Elizabeth City, N. C., November 15 and 16, 1911. Compiled by Joseph Hyde Pratt. 40 pages, 8vo. Raleigh, State Printers, 1912.

University of Kansas. Engineering Bulletin No. 2—Natural gas: its properties, its domestic use, and its measurement by meters. A report published by the Public Utilities Commission of the State of Kansas. Prepared by P. F. Walker, Professor of Mechanical Engineering. 38 pages, illustrations, 8vo. Lawrence, Kan., University Engineering Experiment Station, 1912.

Royal Institution of Great Britain: Weekly evening meeting—February 9, 1912, Very high temperatures, by John Allen Harker, 12 pages, illustrations, 8vo.; February 24, Mouvement Brownien et Grandeurs Moléculaires par Prof. Jean Perrin, 19 pages, illustrations, 8vo.; March 1, The total eclipse of the sun, April, 1911, as observed at Vavau, Tonga Islands, by William J. S. Lockyer, 13 pages, illustrations, 8vo.; May 3, The use of pedigrees, by W. C. D. Whetham, 9 pages, 8vo.; May 10, The Gaumont speaking cinematograph films, by Prof. W. Stirling, 12 pages, illustrations, 8vo.; May 24, Recent advances in agricultural science, The fertility of the soil, by Sir William Crookes, 9 pages, 8vo. London, Institution, 1912.

BOOK NOTICES.

METHODS OF ORGANIC ANALYSIS, by Henry C. Sherman. Published by the Macmillan Company, New York. (2nd edition.) 407 pages, 21 x 14 cm. Price, $2.40.

This book is an advanced laboratory manual of organic analysis, both proximate and ultimate. The order of topics corresponds roughly to that usual in text-books of organic chemistry. However, the scope of the book is broad, and it is not restricted to topics of purely scientific interest. Practical matters such as oils and fats, sugars, soap and food-preservatives receive very detailed discussion, while the treatment of the subject of fuels is the best that the reviewer has seen. The only criticism which occurs to the reviewer is that the whole character of the book seems somewhat advanced for the class of students for whom it is intended—third-year men in the chemical course at Columbia University. The reviewer has met few third-year students who could successfully use a work of this sort without much additional guidance from the instructor.

The book is clearly and concisely written. There are few illustrations, but the bibliographies are unusually complete, and there are many references to the journal literature. There is a good index.

ROBERT H. BRADBURY.

INDUSTRIAL ORGANIC CHEMISTRY, by S. P. Sadtler. Published by J. B. Lippincott Company, Philadelphia. (4th edition.) 601 pages, 23.5 x 15 cm. Price, $5.00.

The reviewer has found it an interesting task to examine this book, since he had the pleasure, twenty years ago, of hearing the lectures of which the book is the outgrowth. These lectures were delivered when Dr. Sadtler was Professor of Organic and Technical Chemistry in the University of Pennsylvania.

The book fills a middle space between the large exhaustive special works and the smaller students' hand-books, like Post, Medicus and Ost in German, Payen in French, and Frank Hall Thorp in English. The difficulties which stand in the path of the author of a work of this kind are very great. It is an unfortunate fact that technical journals do not attain to quite the same high standard of reliability as purely scientific publications. Further, the problem of adopting a consistent, symmetrical, well-balanced treatment, and adhering to it throughout, is not an easy one.

The present work gives constant evidence that the author has appreciated the difficulties of his task and has been willing to take the trouble to overcome them. The revision has been thorough and the book appears to be completely abreast of the present state of the subject. The sections on special analytical methods will be of interest to the working chemist. There are few references to the journal literature, but the bibliographies at the ends of the sections are complete and up to date. The book fills a vacant place in the literature, and fills it well. It should be of great service, not only to chemists but also to teachers.

ROBERT H. BRADBURY.

ANALYST'S LABORATORY COMPANION, by Alfred E. Johnson. Published by P. Blakiston's Son & Co., Philadelphia. (4th edition.) 164 pages, 18.5 x 12 cm. Price, $2.00.

While this book contains some descriptive matter, it is, in the main, a collection of numerical data intended for the commercial analyst. There are tables of atomic weights, percentage compositions, conversion factors for gravimetric analysis, factors for volumetric work, special tables for water analysis, tables for sugar analysis, tables of Reichert-Meissl values, and countless other tables. Most of the data have been recalculated so as to be in accord with the international atomic weights for 1912. The five-place logarithm of each factor is given. The book is a serviceable compilation, which should be very helpful to the practical analyst.

ROBERT H. BRADBURY.

CHEMICAL ARITHMETIC AND CALCULATION OF FURNACE CHARGES, by Regis Chauvenet. Published by J. B. Lippincott Company, Philadelphia. 302 pages, 22.5 x 15 cm. Price, $4.00.

This is a book of rather unusual type. The first two-thirds is devoted to an elaborate and detailed treatment of the whole subject of chemical calculations, covering somewhat the same ground as Biehringer's "Stochiometrie." Illustrative problems are worked out and a large number of problems for class-room work is provided. There are some amusing and pertinent remarks on the unwisdom of stating results to half a dozen decimal places when the limit of accuracy of the method used is reached in the first. The author is to be congratulated on having given the answers to all of his problems. It is a curious anomaly that books in chemical arithmetic are frequently published without answers. The fact is that any teacher can invent without difficulty all the problems he needs for his classes. The difficulty arises in trying to get time in the class-room to do the arithmetical work of solving them, and when, as is often the case, each student is working at a different problem, the difficulty becomes an impossibility. A problem book without answers is little better than waste paper.

The last third of the book is devoted to the application of the principles of chemical arithmetic to the problems that arise in the calculation of furnace charges in iron and copper metallurgy. The book seems to be intended mainly for students and teachers of metallurgy, and it should have a useful career.

ROBERT H. BRADBURY.

PENROSE'S PICTORIAL ANNUAL. The process year book. Edited by William Gamble, 1911–1912, vol. 17, 224 pages of text, 80 pages of illustrations, and numerous plates. 8vo. London, A. W. Penrose & Co., Ltd. American agents, Tennant & Ward, New York, N. Y. Price, in cloth, $2.50.

The volume, which recently appeared from the press, contains the usual number of interesting and valuable contributions to the process engraver's art from workers in all parts of the world. The specimens of half-tone illustrations and color plates give an indication of the progress made during the past year, and the color work includes examples made by various processes and in several colors—from one to five. The presswork and binding have received the same care and attention as those of previous issues.

CARNEGIE INSTITUTION OF WASHINGTON. Publications: The following volumes are now in press:

Barus, Carl—The Production of Elliptic Interferences in Relation to Interferometry. Part II. 8vo.

Stager, Henry W.—A Sylow Factor Table of the First Twelve Thousand Numbers, Giving the Possible Number of Sub-groups under Sylow's Theorem of a Group of Given Order between the Limits of 0 to 12,000.

Lehmer, Derrick N.—Tables Giving a Complete List of Prime Numbers between the Limits 1 and 10,006,721. Folio.

Benedict, Francis G.—The Composition of Atmospheric Air. 8vo.

Benedict, Francis G., and Walter G. Cady.—A Bicycle Ergometer with an Electric Brake. 8vo.

Jones, Harry C.—The Electrical Conductivity, Dissociation, and Temperature Coefficients of Conductivity (from Zero to Sixty-five Degrees) of Aqueous Solution of a Number of Salts and Organic Acids.

CURRENT TOPICS

Ammonia and Nitric Acid from the Atmosphere. PROF. A. W. CROSSLEY D.Sc., F.R.S., (*Engineering,* xciii, 2418, 599.)—This is an abstract of two lectures delivered at the Royal Institution, London. This article deserves careful consideration; the chief points are as follows. The cycle of the changes of nitrogenous matter in the household of nature is: Plants take up nitrates and ammonium salts from the soil and build up organic compounds, which form the food of animals. In the animal system the nitrogenous matter is transformed into proteins to form tissues, and some nitrogen is secreted again as urea and returned to the soil; there the compounds are broken down and re-transformed into nitrates and ammonia again by bacterial action. Unfortunately the wastage in this cycle is enormous at several stages, especially as regards the sewage, some nitrogen is also liberated as such and returned to the atmosphere. Electric discharges in the atmosphere and certain bacteria could fix part of the atmospheric nitrogen; but these sources of supply are quite insufficient and other sources must be sought. The present sources, *e.g.,* guano-beds and Chili saltpetre, might last another twenty to forty years. Ammonium sulphate was produced in great quantity, but still the supply was insufficient. The atmosphere contained some 4,000 billion tons of nitrogen and that above each acre about 32,000 tons of nitrogen, which had to be utilized. The synthetic production of ammonia did not look very hopeful so far. It was known that magnesium would fix atmospheric nitrogen as magnesium nitride, which when decomposed by steam, yielded ammonia; aluminum probably would do the same. Nitrogen is also fixed by the alkaline earth carbides, forming nitrolim, which is a mixture of carbon and calcium cyanamide. This nitrolim was utilized as a manure, or was transformed into other chemical products. Much atmospheric nitrogen was directly oxidized by the electric discharge.

New Composite Sheet Metals. ANON. (*Brass World,* viii, 5, 176.)—The high price of tin has made it desirable to replace it with a cheaper metal. The Hoyt Metal Co., of St. Louis, Mo., have succeeded in producing some very interesting compound soft metals with an aluminum core. The *Hoyt-Silver* is a Britannia metal with a core of aluminum. It will make silver plated ware that is cheaper, stiffer, lighter and stronger than that made from Britannia metal. Its use saves 4 to 5 cents a pound. Sheet as thin as No. 26 B and S gauge is supplied up to 24 inches wide. Hoyt-silver is not suitable for toilet-ware, but another new material called "two-ply Britannia" is supplied for this purpose. *Alumintin* is sheet aluminum faced on both sides with pure block tin. It can be soldered and electro-plated without difficulty. Its specific gravity is 3.34. Such a light material that can be worked like copper will be much appreciated. It is supplied in sheets of the same dimensions as "Hoyt-Silver." *White Copper Stamping Metal* is sheet aluminum faced on both sides with an antimonial lead alloy. It is cheaper and more easily worked than copper or brass, and is stiffer and harder than antimonial lead. It is used for the manufacture of badges, fobs and medals. Its specific gravity is 5.10. It can be stamped into intricate designs without annealing. The dies are not worn, and it can be readily electro-plated. The Hoyt Metal Co. state that these metals are made by a rolling process, which they do not wish to divulge at the present time.

A New Pyrophoric Alloy. ANON. (*Brass World,* viii, 5, 180.)—The usual pyrophoric alloy, used for self-igniting match boxes or gas lighters, consists of 70 per cent. cerium and 30 per cent. iron. A German inventor has found that alloys of manganese and antimony are also pyrophoric and are cheaper than the cerium alloys. For certain purposes it is an improvement to add 10 per cent. of chromium, and during the melting of the alloy it is an advantage to add a very small quantity of aluminum or magnesium to increase fluidity and soundness. The proportions found best are:—

Manganese	80 per cent.
Antimony	10 per cent.
Chromium	10 per cent.

Instead of giving a shower of sparks like the cerium alloys, it produces a long streak of flame, thus making the friction wheel unnecessary. The alloy is air proof and does not disintegrate like the cerium alloy.

Drying Blasts with Calcium Chloride. HEYM. (*Oester. Z. Berg.-Hüttenw.*, lix, 603.)—The cost of plant construction for drying air by calcium chloride is only one-quarter that of a Gayley refrigerator plant of the same capacity. The cost of maintenance is less, also. The method followed is: crushed calcium chloride is sifted to get the fine portion at the bottom and the coarse on top. A spiral tube is inserted in this layer for the circulation of water. The air to be dried is blown through the layer of calcium chloride from above. The heat evolved by the absorption of the moisture is carried off by the water circulating in the tube, which prevents an increase in temperature, as the power of calcium chloride to absorb moisture diminishes the higher the temperature. Care must be taken that the calcium chloride does not get wet. To regenerate it, it must be gradually heated to 175° C. and cooled, when it is ready for use again. Two hundred and forty kilograms calcium chloride spread 24 cm. deep to a square metre are able to dry 300 cubm. air for four hours, whereby 15 grammes moisture per cubic foot were absorbed. Three units are necessary—one in service, the contents of another being regenerated, and the third in cooling.

Asbestos Cement Boards. K. A. Weniger. (*Papierfabrikant,* x, 247.)—Sheets that are useful as a substitute for slate, etc., are composed of asbestos and cement. They are manufactured on paper-making machinery similar to that used for book-binders' boards. A cylinder machine, having two cylinders, 860 mm. in diameter and 1,300 mm. wide, can produce 500 to 600 square metres of board 3.5 to 4 mm. thick, in ten hours. The crude asbestos is disintegrated in an edge runner and charged into the beaters together with cement and coloring matter. The cement is ground and sifted through a screen with holes 5 mm. wide and 10 mm. apart before it enters the beating engine. The charge for the beater is 150 kilos of dry asbestos, and it requires 12 to 15 horse-power. The beaten pulp passes into an agitating drum, thence through strainers with slits 0.8 to 1.0 mm. wide to the cylinder board-machine. The cylinders are covered with No. 50 mesh wire gauze, supported by a No. 5 mesh wire; they run at a speed of 20 to 25 m. per minute. The web of stuff is couched in the usual way, passing with the felt over a suction box, and is collected on the press roll with about 55 per cent. of moisture. The couch-rolls have a diameter up to 2,000 mm. and are mounted on oil buffers to absorb the shock when the board is removed. The boards are cut at once to a suitable size, then placed singly between iron plates previously greased with "petroleum and oil," and submitted to heavy pressure in hydraulic presses; in a few hours they have set as hard as stone. The solid matters in the black-waters from the board machine are collected in filters and the moist stuff is returned to the heaters. In certain cases the hardened boards must be steeped for a long time in running water to remove crystallizable salts.

Alloys and Electrolytic Deposit of Radium. F. de Mare and C. Jacobs. (*Bull. Acad. roz. Belge,* 1912, 53.)—By the reduction of a mixture of silver chloride and radium sulphate with calcium carbonate and charcoal in a gas-furnace a radium-silver alloy was produced. It was radio-active, of a yellow color, showed a gray fracture, and could, with care, be drawn to a thin wire. By electrolysis of a solution of radium acetate between platinum electrodes, a coherent, brown, very active deposit was obtained on the cathode. It is stated that at a definite thickness quartz allows the passage of the light rays emitted by a radium salt, whilst absorbing the α, β, and γ rays.

How and When Diamonds were Made by Nature. R. B. CROCKER. (*Chem. News,* civ, 248.)—Facts are given from which the theory is deduced that diamonds were formed before organic matter, when the earth's atmosphere consisted mostly of CO and CO_2, and the metallic elements were in the molten state. Molten iron, solidifying in fissures and cavities filled with CO and CO_2, imprisoned them, and, under the enormous pressure due to cooling and contracting the oxygen united with the iron and the carbon crystallized as diamond.

Tungsten Carbide for Meter Jewels. ANON. (*Brass World,* viii, 5, 177.)—It is claimed that tungsten carbide is sufficiently hard for use as meter jewels. A bead of metallic tungsten is obtained by fusing the powdered metal in an electric furnace. These beads are then heated in a carbon tube furnace of the electric resistance type. The carbon vapors are absorbed by the tungsten and a very hard tungsten carbide is formed. The carbon lowers the melting point of the tungsten so that it fuses, and when it cools there is a depression in the top of the bead, which renders the subsequent drilling and polishing as a meter jewel less difficult.

Cerium-Aluminum Alloys. R. VOGEL. (*Zeit. Anorg. Chemie,* lxxv, 41.)—The alloys of cerium and aluminum were submitted to a combined thermal and microscopical examination, and an equilibrium diagram of the system is given. The metals combine to form the compounds Ce_3 Al, Ce_2 Al, Ce Al, Ce Al_2 and Ce Al_4, the last undergoes transformation at 1005° C., the β form passing on cooling, with a contraction in volume, into the more stable α form. The alloys, unlike those of cerium with lead and tin, are almost unaffected by air or water, only those containing less than 25 atoms per cent. of aluminum being very slowly attacked. The compound Ce Al_2 is not appreciably affected by strong hydrochloric, nitric or sulphuric acid, and the alloys generally are less readily attacked by acids than the constituent metals. They may be burnt in the Bunsen flame, but only those rich in cerium are pyrophoric. The maximum hardness about 6 on Mohs' scale, is shown by the compound Ce Al_2, which is very brittle and has a melting point 600° C. above that of cerium and 800° C. above aluminum.

Solution of Copper in Water. J. PIONCHON. (*Comptes Rend.,* cliv, 865.)—A cell formed of two plates of copper with water as an electrolyte shows a momentary current when one of the plates is lightly tapped, the tapped electrode becoming negative. If the water is in contact with the copper plates for some time, this effect disappears, but it may be renewed by changing the water. This behavior is supposedly due to the solution of minute traces of copper by the water, in too small a quantity to be detected chemically; but the water rendered inactive becomes active again after shaking with iron. It is claimed that by this method it can be stated whether water has been in contact with copper, when no trace can be detected by ordinary methods.

Vapor Pressures of Alkali Metals. L. Hackspill. (*Comptes Rend.,* cliv, 877.)—The vapor pressures, between 250° C. and 400° C., were measured by sealing the metal in a U-tube, one limb of which was kept at the required temperature, and the other just above the melting point of the metal. From the observed changes of level of the metal in the two arms of the tube, together with the density at the melting point, and coefficient of expansion of the liquid metal, the vapor pressure can be calculated. Figures and curves are given for cœsium, rubidium, potassium, and sodium. The highest vapor pressures measured were:— cœsium, 15.88 mm. at 397° C.; rubidium, 6.14 mm. at 367° C.; potassium, 4.61 mm. at 400° C.; and sodium, 0.26 mm. at 397° C.

Preservation of Wood with Fluorides. R. Nowotny. (*Oester. Chem. Zeit.,* xv, 100.)—To increase the preservative effect of sodium fluoride on wood, it is mixed with nitrophenols; one of these mixtures, Bellit, consists of 90 parts of 90 to 95 per cent. sodium fluoride and 10 parts of dinitro phenolanilin. This compound is active as an antiseptic; but does not, like free dinitrophenol, act upon the iron vessels in which the timber is impregnated. The selective phenomena observed when treating timber with mixtures of zinc fluoride and hydrochloric acid are reproduced in the Bellit treatment. Impregnation by steeping results in the solution being absorbed as a whole, but in the hydrostatic and pneumatic pressure methods the nitro-compound is absorbed more rapidly than the fluoride. Examination of telegraph poles, which had been treated in 1905 and 1906, with copper sulphate and zinc fluoride respectively, has shown that in general the latter is much the better preservative.

"Sickness" of Aluminum. Robt. Grimshaw. (*Metal Ind.,* x, v, 194.)—Tin, when subjected to severe cold, is subject to a disease known as the "tin-pest," and it has lately been discovered that aluminum is subject to a similar disease, which decomposes it. The first to mention this was Ducru, head chemist of the technical section of the French Artillery. Prof. Heyn then took the matter into consideration, together with Prof. Bauer, in the laboratory of Gross-Lichterfelde near Berlin. The hypothesis they offer in explanation is that in the rolling process two neighboring strips of the sheet metal attain different degrees of electrical tension, and when they come in contact with a solution of a salt, act as two different metals in electrolysis; the hardest worked strip playing the part of the positive electrode and being decomposed. As a preventive it is recommended to heat the metal to 450° C. or 842° F. There is, however, reason to fear that such a temperature would make the articles soft and less durable.

Artificial Pumice Stone. ANON. (*Amer. Mach.*, xxxvi, 15, 590.)—Natural pumice is so common to volcanic eruptions that with such outbursts the surface of the adjacent sea is covered with the floating stones. The material is a kind of obsidian which has been rendered porous, while in a molten state, by the expansion of gas or steam in its substance. Pumice is not always reliable, for it will vary in grain and hardness, sometimes in the same piece. An artificial pumice is now being made at Bietigheim in the valley of the Enz. Its constituents are sandstone and clay, and ten different grades are manufactured. There is a hard and a soft kind designed for leather, felt and wood industries; another kind for stucco workers and sculptors; a soft finely grained variety for polishing woods and tin goods; another for lithographic stones; while other varieties are prepared suitable for various duties.

Solid Oxygen by Evaporation of the Liquid. J. DEWAR. (*Roy. Soc. Proc. Ser. A.*, lxxxv, 589.)—It is more difficult to solidify oxygen than hydrogen or nitrogen, because oxygen has a small vapor pressure at its melting point. With the aid of cocoanut charcoal (75 gm.), as much as 10 c.c. of liquid oxygen have been changed to a transparent jelly within a silvered, vacuum jacketed tube placed inside a wider tube filled with liquid air. The pressure required for solidification was determined by a McLeod gauge at 1.12 mm.; the melting point would be 53.3° K. by extrapolation from Willard Gibbs's vapor tension formula. A subsequent determination by a hydrogen thermometer gave 54° K., while Kamerlingh Onnes finds 54.6°.

New Hard Fired Porcelain Colors. W. PUKALL. (*Sprechsaal*, xlv, 211.)—New colors are obtained by allowing suitable refractory, porous, colorless bodies, such as aluminum hydroxide, silicic acid, Zettlitz kaolin, zinc oxide or a mixture of zinc oxide with aluminum hydroxide in the ratio of 1 ZnO, 2 $Al_2 O_3$, meta-stannic acid, calcium phosphate, etc., to absorb easily soluble metallic salts which yield coloring oxides, and then calcining at Seger cone 7, whereby the salts are decomposed. Cobalt oxide with alumina, or with alumina and zinc oxide, or with silicic acid as the basis, gave tones ranging from the most delicate ultramarine to the deepest dark blue, suitable for porcelain and earthenware. Chromium oxide in very small amounts, with an alumina basis, gives reddish gray tones, especially under a glaze rich in magnesia. With the alumina-zinc oxide basis, 0.2 molecule of chromium to 0.5 ZnO, Al_2O_3 gives bright pink colors, which beyond that amount turn to reddish-gray. By saturating AlOH with manganese nitrate so as to produce on ignition a body with the composition Al_2O_3, 0.15, to MnO, 0.2, a violet red, is obtained which is changed to brown by larger amounts of MnO. Colors with 0.1 to 0.3 molecules of Fe_2O_3 to 1 molecule of alumina, stand fairly well under stoneware glazes, though somewhat brownish-red in appearance. Serviceable, red under-glaze stoneware colors are given by mixtures of 0.2 to 0.8 molecules of ferric oxide to 1 molecule of calcium phosphate as the basis. Copper red under-glaze colors can be produced by copper nitrate with alumina or with silicic acid as the basis, though the latter gives a brighter and more reliable effect. With 1 molecule of silica a bright red is produced with only 0.4 molecule of cupric oxide. Bright to dark brown colors are produced on porcelain from uranium nitrate, with 0.2 to 1.0 molecule of uranium trioxide to 1 molecule of alumina, silicic acid, or Zettlitz kaolin. Under an alkali glaze upon stoneware very bright orange yellows are obtained.

Moisture in Coal. E. H. ARCHIBALD and J. N. LAWRENCE. (*J. Ind. Eng. Chem.*, iv, 258.)—Experiments on the drying of bituminous and anthracite coal under different conditions are described which show that the U. S. A. official method (heating for 1 hour at 104°–107° C.) gives figures for moisture, which are much below the true value; the error in the case of some bituminous coals amounting to 40 per cent. of the true content of moisture. The errors, probably mainly due to the oxidation of iron, or sulphur, or both, and to the incomplete expulsion of moisture, are much greater for bituminous coal than for anthracite. For determining moisture in bituminous coal, it is recommended that the coal be heated in a current of dry air at a temperature not below 110° C. and the moisture expelled be absorbed by anhydrous calcium chloride.

Influence of Silicon on the Properties of Iron. P. PAGLIANTI. (*Metallurgie*, ix, 217.)—A series of iron-silicon alloys was produced containing from 0.24 to 5.26 per cent. of silicon; 0.12 to 0.15 of carbon, 0.23 to 0.60 of manganese, 0.4 to 0.64 of sulphur, and 0.31 to 0.45 per cent. of phosphorus. They were examined in the cast, annealed and quenched conditions as to their fracture, tenacity, elongation, contraction of area, hardness, resistance to bending, specific gravity, electrical conductivity, and magnetic permeability, and the results are tabulated and illustrated by curves. The conclusions are:—(1) Silicon raises the yield point and increases the hardness and tenacity, while it diminishes the elongation and contraction in area of untreated, annealed and quenched alloys. (2) The resistance to bending (of notched bars) is changed very little up to 1.40 per cent. of silicon, and is diminished when the silicon content exceeds 1.60 per cent.; annealing and chilling increase the brittleness, (3) the specific gravity diminishes as silicon increases, (4) electrical resistance rises with increasing silicon, (5) the addition of silicon to iron improves it magnetically by increasing the permeability and decreasing the hysteresis, 2 per cent. of silicon gives good results. The best magnetic results were obtained by annealing a 2 per cent. silicon alloy. The paper is illustrated by 10 microphotographs, and there is a summary of previous work.

Use of Coke-Oven Gas for Cities in Germany. G. S. COOPER. (*J. Gas-Lighting,* cxviii, 107.)—The towns of Waldenburg, Altwasser, and Salzbrun in Silesia, Essen, Dortmund and Mülheim have, for some time, been supplied with gas from neighboring coke oven plants. The entire supply of Mülheim-on-the-Ruhe and of Barmen, about 40 miles distant, is obtained from two coke oven plants. The installation consists of 50 Koppers' horizontal regenerator ovens, each capable of taking from 8 to 10 tons for a charge, the time of carbonization is 24 hours and only the richer portion of the gas—that evolved from the second to the twelfth hour, which is about 50 per cent. of the yield—is used for distribution. During this period one oven will produce 70,600 cubic feet of gas of a calorific value well over 600 B.t.u.'s per cubic foot with the average composition—CO_2 1.2, CO 6.8, H 49.5, CH_4 38.3, and N 4.2 per cent. A yield of 65 to 69 per cent. of large coke, 5 to 6 per cent. of tar, and 1.3 to 1.5 per cent. of ammonium sulphate is obtained. The gas costs 17 cents per 1000 cubic feet, and is sold for 70 cents per 1000 cubic feet.

The Purity of Aluminum. ROBT. GRIMSHAW. (*Metal Industry,* x, 6, 238.)—The aluminum in the market is generally impure, most of it contains silicon and iron. Mierzinski states that the presence of foreign metals makes aluminum hard and brittle; 5 per cent. of iron or copper renders it almost unworkable; 10 per cent. of copper makes it as brittle as glass, and it blackens in the air. It remains perfectly workable with 50 per cent. of silver and takes a beautiful polish. With 10 per cent. of gold its malleability remains unchanged, and its hardness is increased. If 0.1 per cent. of bismuth is added to it, the aluminum becomes so brittle that it is unworkable even after annealing.

Potash from Alunite. ANON. (*Oil, Paint, and Drug Reporter,* April 22, 1912.)—As continued interest is displayed in many places in the prospective discovery of potash in the United States, the Geological Survey has reissued a report made by Hoyt S. Gale on alunite, a potash bearing mineral, found in a newly discovered deposit near Marysvale, Utah. This alunite is of special interest as the potash it contains is believed to be commercially soluble, that is, it can be obtained as a fertilizing material by simple roasting and leaching of the rock. The bulletin describes a vein believed to be of considerable size, which though it can not supply the whole

American demand, may meet local needs. The commercial development of this deposit will be of the greatest importance in stimulating exploration for other similar deposits. Alunite has been observed by other members of the Geological Survey at several points in many Western States, and it may be expected that further prospecting and investigation will disclose deposits that may yield a large tonnage.

Iron Ore Deposits in Norway. ANON. (*Engineering*, xciii, No. 2415, 481.)—The South Varanger iron ore deposits are being actively worked and important extensions have been made. They supply a practically new product, a concentrated iron ore, termed "Slig" to the international market. The iron ore is got by quarrying, rather than by mining methods; and the blasting operations are on an unprecedentedly large scale. The area blasted on one occasion was between 60 and 70 metres long, one end 10 m. wide and the other 20 m. wide, and 11,000 cubic metres of iron ore were displaced, or about 38,500 tons. The export quay is built of concrete blocks with two electric cranes of a capacity of 150 tons per hour. The coal discharging quay is 50 m. long with a crane that can discharge 800 tons per day.

Condensite. ANON. (*Elect. Rev. and West Electri.*, lx, 199.)—This is a new insulating material, produced by J. W. Aylesworth, by the action of phenol on formaldehyde. It resembles gum, is transparent, hard, insoluble in alcohol and of high dielectric strength, and does not fuse or soften when heated. In solution it can be used as an air-drying varnish, oven-drying enamel, or as a cement. It can be adapted for impregnating electrical apparatus or for moulding. It is said to be uninflammable, non-hygroscopic and an insulator for heat as well as electricity. Its tensile strength is about 4,000 lbs. per square inch with a compressive strength of 22,000 lbs. per square inch when cold, and 11,000 lbs. when hot.

Manufacture of Balloon Fabrics. CHURREL. (*Gummi-Zeit.*, xxvi, 894, 938, 972, 1016 and 1055.)—Fabrics should be of the best quality, preferably Egyptian Sea Island cotton. The fabric should be freed from sizing materials by sufficient washing; it should give practically no starch reaction with a potassium iodide solution of iodine. Mechanical tests should be made on samples which are neither quite dry nor too wet. Fine, hard Para rubber should be used for coating, though it may be replaced by Peruvian Ball or smoked plantation sheet rubber up to 40 per cent. if the vulcanization is carefully done. Soft Para or Peruvian Tails or deresinified Guayule are unsuitable, as the rubber on the fabric resinifies with time. Good mixings are: (1) To secure impermeability by gas: 400 parts of hard fine Para rubber, 3 of paraffin (melting point about 66° C.), 40 of sulphur, and 17 of magnesium oxide; (2) to raise the tensile strength of the fabric: hard fine Para rubber, 400; paraffin (m. pt. about 66° C.), 4; magnesium carbonate, 260; magnesium oxide, 36; and fine sulphur, 40 parts. All powders should be sifted twice; (3) to obtain impermeability to gas in cold-cured fabrics: fine hard Para, 400; paraffin (m. pt. about 66° C.), 5 parts. Benzine and benzol, free from water or suspended iron-oxide, are suitable solvents. The boiling point should be between 70° and 100° C., and not more than 8 per cent. should boil over 100° C. The rubbered fabrics are prepared and combined on a smooth calender. Vulcanization is done on drums by steam, or if sensitive colors or fabrics are used, by hot air under pressure. The fabrics must be protected from direct access of steam, 50 to 90 minutes cure at not exceeding 133° C. and 2.2 atmospheres is suitable. With hot air 1 to 2½ hours at not more than 129° to 130° C. at 4 to 6 atmospheres is suitable. It is best to aim at a slight undercure to allow for after-vulcanization.

"Sulphinol." A New Photographic Developer. J. DESALME. (*Bull. Soc. Franc. Phot.*, iii, 94.)—The most efficient photographic developer of the hydroxydiphenylamine derivatives is *p* amino-*p*'-hydroxydiphenylamine-*o*-sulphonic acid known as "Sulphinol." It is slightly soluble in water, but readily soluble in alkalies and alkaline carbonates. It gives soft images of good gradation with pure whites; under normal conditions the image appears in about 3 minutes and development is complete at the end of 7 or 8 minutes. The developer is very sensitive to bromide. A developing bath for papers may consist of sulphinol, 10 to 15 grammes; crystallized sodium sulphite, 40 to 50 Gm.; "dry" sodium carbonate, 20 to 30 Gm.; water, 1000 c.c. Satisfactory results are obtained in developing negatives by using sulphinol and quinol, *e.g.*, sulphinol, 10 Gm.; quinol, 5 Gm.; sodium sulphite, 50 Gm.; sodium carbonate, 50 Gm.; water, 1000 c.c. The developing solutions are stable.

Propagation of Warm Waves in European and Asiatic Russia. H. v. FICKER. (*Akad. Wiss. Wien. Ber.*, cxx, 2a, 745.)—The lines which connect spots of simultaneous rises of temperature, are, on the whole, meridional, but may be strongly curved, and warm and cold currents may then proceed on parallel paths. The general drift of the currents is eastward. Most warm waves are preceded and followed by cold waves. Islands or tongues extend into the cold areas from the warm areas. The winds bringing warm weather mostly blow from the southwest fairly in the direction of the warm wave, while the cold waves come at right angles to it. The temperature maxima with warm waves differ much less from one another than with cold waves. Sometimes a warm wave may be traced from the Atlantic and Arctic shores right over to Eastern Siberia; but they generally vanish before they cross Lake Baikal. The rate of propagation is about 33 Km. per hour, about the same as cold waves, and the two kinds of waves are probably interconnected. The humidity observations suggest that the warm waves arise in the ocean. The abnormal heating of continental areas is confined to shallow surface strata as a rule. Warm waves develop mostly in the front of a depression, and cold waves in the rear of the depression, the centre of which generally lies near the polar boundary of the warm area; these depressions consist of two neighboring currents of different temperatures. It appears, in general, that the warm southwesterly winds are always blowing as part of the general circulation, and that they are temporarily lifted from the surface and pressed upward by the invasion of cold waves, which also belong to the general circulation. The phenomena are simpler in Russia than elsewhere because the temperature variations are more pronounced there, though caused by abnormal temperatures in relatively shallow strata.

The Effect of Steam on Portland Cement.—The Bureau of Standards, of the Department of Commerce and Labor, in connection with the investigation of structural materials is conducting a series of tests to determine the action of high-pressure steam on Portland cement. It has been found that high-pressure steam will greatly accelerate the hardening of certain cements, increasing their strength several hundred per cent., but will cause the complete disintegration of other cements which under normal conditions appear to have the usual physical qualities. The present investigation is in part an extension of the work reported in Technologic Paper No. 5, "The Effect of High-Pressure Steam on the Crushing Strength of Portland Cement Mortar and Concrete." The equipment for this purpose consists of a small steam-pressure tank, or so-called "autoclave," suitable for pressures up to 50 atmospheres (515 pounds per square inch); and a large cylindrical steel tank, 12 inches by 5 feet inside dimensions, suitable for working pressures up to 70 atmospheres (1,030 pounds per square inch).

It has been proposed that specifications for the purchase of Portland cement be amended to include a test of exposing cement to a steam pressure of 20 atmospheres (294 pounds per square inch) for a period of two hours. It is required that the cement remain sound and that the tension briquettes show a given increase in strength.

It has been found that certain cements which meet the steam test of 212° F. for five hours, as required by present specifications, fail under the proposed high-pressure steam test. In investigating the cause and interpretation of this failure, practically all brands of cement purchased by the Government are being subjected to the high-pressure steam test in connection with the regular routine specification test, and much valuable information is being accumulated.

Tests are also being made on specially prepared cements of various degrees of fineness and after seasoning for different periods. Other series of tests are being made in exposing cements neat, and in mortars and concretes to a series of pressures ranging up to 1,000 pounds per square inch and for various durations. Tensile and compressive strength, linear expansion and contraction, water absorption, and other physical properties are being determined. The effect of temperature, pressure, and moisture content of the atmosphere, or degree of water saturation, is being studied independently.

Some interesting results are also being obtained by subjecting to high-pressure steam pieces of mortar and concrete from sound and disintegrated structures which have been in place for several years.

To determine the value of the high-pressure steam test as a determination of the soundness and structural quality of Portland cements, a large number of concrete cylinders, 8 inches in diameter by 16 inches in length, are being made of cement which fails to meet the normal 212° F. steam test, as well as of cement which passes this test but fails to meet the proposed 20 atmosphere steam-pressure test, and of cement which meets both of the above requirements. The cements are being tested in a normal 1:2:4 proportion concrete mixture, and will be exposed in various localities over a period of years and tested for elastic properties and compressive strength.

Photographic Intensification. J. DESALME. (*Bull. Soc. Franc. Phot.*, iii, 96.)—After many trials it has been found that sodium stannite reduces silver chloride most energetically, and produces the most intense silver image. In intensifying by this method the image is converted into silver chloride by means of a 2 to 3 per cent. solution of cupric chloride, slightly acidified with hydrochloric acid. The bleached image is washed and redeveloped in a sodium stannite solution prepared by adding 18 c.c. of NaOH (40° Be.) to 10 Gm. of stannous chloride dissolved in 100 c.c. of water, and diluted to 250 c.c. To obtain warm brown tones the bleached image is treated with a 5 per cent. solution of Na OH before redevelopment. The process is equally applicable to negative or positive silver images.

Carbon Monoxide in Illuminating Gas. ANON. (*Circular of Bureau of Standards,* No. 32, 1912.)—Existing legislation shows no tendency to limit the carbon monoxide content of gas, although it is the only constituent of illuminating gas which, in the amounts ordinarily found, is poisonous. Coal gas contains from 5 to 10 per cent. of carbon monoxide; water gas from 25 to 30 per cent.

To limit the amount of carbon monoxide in the gas sold might limit the amount of water gas made. Such regulations as would prevent the operation of water-gas plants now in existence would be very severe, but the extension of present plants should not be directed toward increasing the use of coal gas rather than of water gas. The use of water gas may possibly not be much more dangerous than coal gas. A large proportion of the cases of death or illness by gas poisoning are suicidal; and the character of the gas would have only a small influence upon the result. A large number of deaths and cases of poisoning called "gas poisoning" are due not to the gas itself but to the carbon monoxide formed by combustion of the gas with insufficient supply of air, due to faulty appliances. It is possible that the protection of the public from danger will be found rather by regulation of appliance, and the general education of gas-users as to proper precautions, than in the limitation of the carbon monoxide content of the gas itself.

Foreign Markets for Motor Vehicles.—As well as supplying the great home demand for motor vehicles, the automobile manufacturers of the United States are annually making great strides in their invasion of the foreign markets, according to a monograph entitled, "Foreign Markets for Motor Vehicles," recently issued by the Bureau of Manufactures, Department of Commerce and Labor. This publication is a compilation of reports from American consuls stationed in every part of the globe, and is arranged with the particular end in view of aiding American manufacturers to extend their foreign sales. It describes the peculiarities of the various markets, special local conditions and prejudices to be considered, foreign competition to be met, and the best methods of selling cars.

Canada is the United States' best market, the majority of the cars in use in that country being either made entirely in the United States, assembled in Canada from parts imported from the United States, or made by Canadian branches or affiliations of American firms. The exports of automobiles from this country to Canada have risen from 1,230 in 1909 to 4,687 in 1911.

The high road-clearance, flexibility, and moderate price of the American car are steadily winning it favor in regions where highway conditions are similar to those in the United States. The market in Australia and New Zealand is already being well cultivated by American exporters, while Argentina, Brazil, and Uruguay, in South America, and British South Africa are named as promising fields for future sales. It is estimated, also, that there are more American than European cars in use in Mexico.

In the Far East, Ceylon, India, Japan, Siam, and the Straits Settlements are the most likely markets. China has little use for automobiles, as most of the roads of that country do not permit their use. In the Straits Settlements the principal buyers are wealthy Chinese, who demand comfort and luxury in their cars rather than high power. As a result, low-hung, smooth-running cars are the most popular, and the local trade often demands that each car be fitted in accordance with the individual taste of the owner. Right-hand drive is essential here, as in the Orient all traffic turns to the left, instead of to the right, as in the United States.

The United Kingdom has been, and continues to be, an excellent market for American cars, ranking next to Canada in purchases from the United States, but the sales in Continental Europe have thus far not been extensive. The excellent roads of most of the European countries permit the use of a heavier, lower-hung car than is found commonly in the United States. In England, however, the low prices and complete equipment of American cars are fast increasing their popularity, while they are rapidly overcoming the prejudice against them, caused by doubt as to their durability, due to the sale of many cheap, unsubstantial American-made bicycles in England some years ago. The method of American dealers of putting their cars on the market fully equipped is in strong contrast with the practice of Continental makers, who quote prices on the chassis only, with the body and all equipment listed as extras.

Action of Acids on Concrete. E. Neumann. (*Tonind. Zeit.*, xxxvi, 601.)—Concrete drains have suffered more or less damage, some of them in comparatively short periods from the time of their construction. In every case the destructive action was traced to the presence of acid in the water which reached the drains either internally or externally. In one case the swampy soil surrounding the drain contained iron pyrites, and the water became charged with sulphuric acid; in the other cases the air in the drains was heavily laden with hydrogen sulphide, which slowly oxidized to sulphur and sulphuric acid. Other mineral and organic acids, such as hydrochloric, oleic, acetic acids and carbon dioxide were found almost as noxious. It is concluded that the destructive action of acids is due to two causes, viz:—(1) The formation of certain calcium and aluminum compounds, especially calcium sulphate, which is accompanied by a large increase in volume; (2) the formation of soluble compounds, especially calcium bicarbonate, which dissolve and cause the concrete to collapse. The chief remedies proposed are:—To provide adequate ventilation inside the drains; to use dense, non-porous clinker, poor in lime, as basis for the concrete; and to cover the exposed surfaces of the concrete with a coat of tar, or, best of all, to protect the foundations of the drains with tar-felt or asphalt.

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THE PRACTICAL ASPECTS OF THE PROPAGATION OF HIGH-FREQUENCY ELECTRIC WAVES ALONG WIRES.*

BY

JOHN STONE STONE.

A NEW art has been born to us. The infant art of high-frequency multiplex telephony and telegraphy is the latest addition to our brood of young electric arts. It is certainly a most promising youngster and should, after the manner of its kind, call lustily for its share of attention and sustenance.

More than twenty years ago the advent of this new art was definitely prophesied by the late J. W. Gibboney [1] and the author [2] in this country, and in France by the well-known electrical engineers Maurice Hutin and Maurice Leblanc. But though there was at that time a vigorous contest for priority which extended over a period of years, it is not with these early records, prophetic though they be, that we have to deal now. They are buried in the archives of the United States Patent Office. Our interest to-day is in the vital practical aspects of the new art, based upon the

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* Communicated by the author.

[1] U. S. Patent No. 481,529, telephony, application filed Feb. 8, 1892, patent granted Aug. 23, 1892.

[2] Interference in the U. S. Patent Office No. 17,197, Stone *v.* Hutin & Leblanc, subject multiple telephony. Record for Stone and record for Hutin & Leblanc.

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propagation of high-frequency electric waves along wires, and certainly, though twenty years ago there seemed to be much promise of the new art, there were, indeed, surprisingly few practical aspects to the subject.

For the past three years or more Major Geo. O. Squier, of the Signal Corps of the United States Army, has conducted a systematic investigation of the propagation of high-frequency electric waves along wires and of the practicability of their use in the transmission of signals and of speech along actual telephone cables and air lines. His investigations have also dealt with electrical resonance as a means of segregating, at the receiving end of the line, high-frequency currents of different frequencies simultaneously propagated along the line, and the selective reception of the energies of these different currents, each in a different receiver circuit made responsive only to the variations in the amplitude or strength of the current it is resonantly tuned to receive. The results of his labors are to demonstrate beyond a peradventure that not only Morse signals but speech may be transmitted over the ordinary telephone cable and pole line circuits and to very considerable distances by means of high-frequency electric currents or waves, and that a large number of telegraphic or telephonic messages may thus be transmitted simultaneously over a given telephone or telegraph circuit without interfering with each other through the use of electrically tuned or electrically resonant receivers. Moreover, he has shown that the new high-frequency multiplex telegraph and telephone system may be superimposed on the older systems or the new high-frequency apparatus added to lines equipped with the usual telegraph or telephone apparatus without interfering in any way with the operation of this older apparatus or being interfered with by it.[3]

Major Squier has dedicated to the public his patents relating to this new art—an act which, though laudable in the spirit it displays, is nevertheless unfortunate, as it is more likely to retard the progress of the new art than to advance it, since what is everybody's business is nobody's business, and capital may hesitate to enter a new field and promote an undertaking in which it is led to believe that it will meet with unrestricted competition as the reward for its enterprise.

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[3] Paper by Geo. O. Squier in the *Proceedings A.I.E.E., May,* 1911. U. S. Patents to Geo. O. Squier, Nos. 980,356, 980,357, 980,358, 980,359, all granted Jan. 23, 1911, and all dedicated to the public.

The frequencies of the electric waves or currents propagated along the wires in this new art are, so to speak, " above the limit of audibility of the receivers " or are ultra-sound frequencies. In other words, each of the electric currents propagated along the telegraph or telephone line is of so high a frequency that it can produce no audible effect in the telephone receiver through which it passes as long as its strength or amplitude remains constant. In fact, the frequencies of the currents used in this new telegraphy and telephony are 20,000 or more alternations per second, and correspond, therefore, to the frequencies of the air vibrations of sounds whose pitches are above the limit of audibility of the human ear. In the new telegraphy and telephony, the telegraphic signals and the voice are transmitted over the line wire by suitable variations in the amplitude or strength of the otherwise uniform high-frequency current, and the signals and the voice are received in a magneto telephone receiver connected in a local circuit which included a device capable of rectifying the high-frequency current used. The rectifier employed is preferably an Audion,[4] though a Wollaston [5] electrode and perhaps other radio-telegraphic detectors, particularly the so-called crystal rectifiers, may also prove serviceable.

The rectifier in the local circuit at the receiver converts the high-frequency current of the line wire into a pulsating current of double the frequency, or, what is the same thing, it converts the high-frequency current into a normally uniform unidirectional current with a superimposed alternating current of double the frequency of the line current. The telephone receiver is mute to the alternating component of the rectified current, but responds to the most minute variations in the strength of the unidirectional component of this current. Variations in the amplitude or strength of the high-frequency line current are faithfully reproduced in the strength of the unidirectional component of the local receiver current, and in this way the telephone receiver is made highly sensitive to variations in the strength of the high-frequency line currents, while absolutely mute to that current when its amplitude is constant.

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[4] *Proc. Inst. Elect. Eng.*, xxv, pp. 219–247, 1906.

Elect. World, xlviii, p. 1109, 1906.

Ibid., xlviii, p. 1186, 1906.

U. S. Patent No. 879,532 of 1908 to de Forest, and U. S. Patent No. 884,110 of April 7, 1908, to J. S. Stone and S. Cobat.

[5] Paper by Dr. Wm. H. Wollaston, *Phil. Trans. of the Royal Soc. of London,* vol. 91, part ii, pp. 430–432, published 1801.

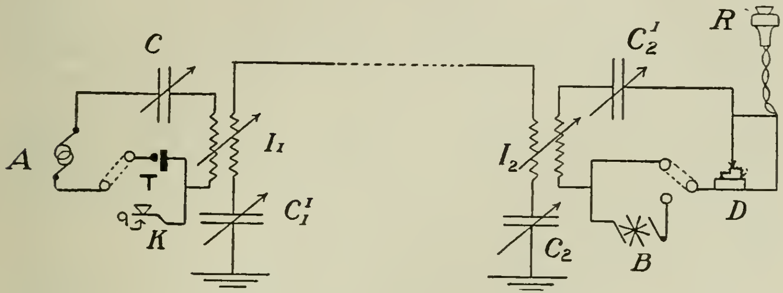
However much the lack of a definite ownership and consequent lack of definite financial backing may militate against the rapid commercial adoption and extension of the new art, there can be little doubt that the actual transmitting and receiving apparatus of either the high-frequency multiplex telegraph or telephone will receive ample attention on the part of inventors and engineers. This apparatus is destined to be and is even now being perfected in its every detail, for the reason that the transmitting and receiving apparatus of the new multiplex telegraph and telephone is identical with that of the new continuous wave train radio-telegraph and radio-telephone respectively. We have here no mere analogy or similarity; it is an identity. Thus a number of continuous wave train radio-telegraphic transmitters connected to a telegraph line and an equal number of radio-telegraphic receivers similarly connected to the line actually constitute one of the new high-frequency multiplex telegraph systems, and correspondingly one of the new multiplex telephone systems may be constructed by attaching a number of radio-telephonic transmitters and an equal number of radio-telephonic receivers to a telephone circuit.

Of course, the perfection of the transmitter and receiver is by no means all or even the most important practical desideratum in the evolution of the new art. For the realization of the great economies this art seems destined to effect in the cost of telegraph and telephone circuits, much will have to be done in the way of adapting the new system to the complex existing and future telephonic exchanges, their mechanisms and net-works of circuits. In its application to the existing telegraph systems less difficult problems will in general have to be met, but even in the application of the new multiplex telegraph to one of the simplest existing telegraph installations it is more than probable that some unforeseen conditions will arise to meet which will require the exercise of some ingenuity and skill.

The relation of the new high-frequency telegraph and telephone to radio-telegraphy and radio-telephony is to be readily seen in Fig. 1, which illustrates the new system in its simplest practical form. The diagram shows, in fact, two radio-telegraph or radio-telephone stations with a connecting wire between them to guide the waves from the transmitter to the receiver.

In this arrangement the current is supplied by a high-frequency alternating current dynamo *A*, which must be capable of supplying 20 watts at 10 volts and at not less than 20,000 cycles per second. These requirements are more than met in the Alexanderson high-frequency dynamo,[6] which has already been constructed to a capacity of at least 2 kilowatts and develops at its highest speed currents of 100,000 cycles per second. In the case of high-frequency telephony this dynamo has to meet a further requirement which is not demanded of it by high-frequency telegraphy, and this requirement is perhaps the most difficult one to satisfy. It is that the amplitude of the current the dynamo supplies must be absolutely smooth and can have no variations or ripples on it of periods corresponding to the periods of audible tones. In this connection the author noted that a 2 kilowatt Alexanderson dynamo gave a loud musical tone in the telephone at the receiving end of the line when the dynamo was worked with the normal separation between the stator and rotar, and he found it necessary to increase the air gap to a point at which the capacity of the dynamo was about one-eighth of its normal rated capacity before a quiet line was secured. Even at this adjustment, however, the dynamo had more than ten times the required capacity.

FIG. 1.



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[6] *Trans. Am. Inst. Elect. Eng.*, vol. xxviii, p. 399.

Owing to the small amount of energy required of the dynamo, there is no particular difficulty in constructing machines to meet the demands, very unusual though they be, particularly in the case of high-frequency telephony. It is not likely, however, that high-frequency dynamos will long be used in this connection, because oscillators giving sustained oscillations or continuous trains of waves of ultra-sound frequencies, constructed on the general principle of the Elihu Thomson oscillator,[7] are very much cheaper and less cumbersome than the dynamo, while requiring less care and skill in their operation. The early Thomson oscillator has been considerably improved, particularly through the use, for uniform cooling of the spark or arc gap, of various devices, such as massive and water-cooled electrodes.[8] Working in this direction, Paulsen [9] has immersed the arc or spark in a gaseous atmosphere of higher heat conductivity than air, while de Forest has gone so far as to immerse the arc or spark in running water. The latest type of this oscillator is described very fully by E. Leon Chaffee in THE JOURNAL OF THE FRANKLIN INSTITUTE for May, 1912, and also in the *Proceedings of the Am. Acad. of Arts and Sciences,* vol. xlvii, No. 9, Nov., 1911.[10]

In the arrangement of apparatus illustrated in Fig. 1, when the switches at the transmitter and at the receiver are both thrown up as shown, the arrangement is a high-frequency telephone system, while when the switches are both thrown to their lower contact points the arrangement becomes a high-frequency telegraph system, so that the one diagram may be used to sketch the operation and requirements of both the new telegraph and the new telephone.

In the new telephone system, when the transmitter T is spoken to, it modifies the amplitude of the high-frequency current in the primary circuit of the induction coil I_1 in exactly the same way that it modifies the strength of the battery current in the primary circuit of the induction coil in the old telephone system, and, as already described, the telephone receiver R at the receiving station responds, owing to the fact that exactly corresponding fluctuations result in the unidirectional component of the rectified current in the local circuit at that station.

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[7] U. S. Patent to Elihu Thomson, No. 500,630, of July, 1892.

[8] U. S. Patents to J. S. Stone, Nos. 767,983 and 803,199.

[9] U. S. Patent to V. Paulsen, No. 789,449.

[10] A further improvement in this oscillator is described in U. S. Patents to J. S. Stone, No. 802,431 of 1905 and No. 946,167 of 1910.

In the new telegraph system the operation of the telegraph key *K*, to send Morse signals, alternately throws the high-frequency current on the line and cuts off the supply of this current from the line. The result of this would be only to make successive faint clicks in the telephone receiver *R* as the current is thrown on and off, except for the periodic interrupter *B*, which may be of the nature of a revolving commutator or a mere buzzer. This interrupter serves to break the incoming wave trains constituting the Morse signal elements up into a succession of much shorter wave trains having a frequency of about 450 impulses per second, which when rectified give rise in the telephone receiver to a high pitched musical tone of great audibility. The Morse signals now are audible as a succession of long and short intervals of a high-pitched musical sound, as in radio-telegraphy. From the foregoing and the diagram of Fig. 1 the essential differences between the new telegraphy and the new telephony will easily be seen.

Some of the more essential characteristics of the simple system shown in Fig. 1 may prove of interest, particularly as they have not as yet, so far as I am aware, been clearly set forth. The induction coils I_1 and I_2 are wound without any iron in their cores, since in the first place the presence of iron is not needed to secure a large mutual inductance between the primary and the secondary circuits, because a high degree of coupling[11] between these circuits is not desirable, and, in the second place, the presence of iron in the core of the coils would introduce a loss of energy, through hysteresis, owing to the high frequencies used, which would give rise to an effect equivalent to the presence of a considerable dissipative resistance in the primary and in the secondary circuits. The arrow through the symbols for the coils indicates that these coils are adjustable with respect to their degree of coupling in the same way and for the same reason that the coupling of the corresponding coils is made adjustable in radio-telegraphy and radio-telephony. Similarly, the arrows through the symbols for the condensers $C_1C'_1C_2$ and C'_2 indicate that these condensers are of adjustable capacity.

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[11] The coupling coefficient of the induction coil is $\frac{M}{\sqrt{L_1L_2}}$, where M is the mutual inductance, and L_1 and L_2 are the inductance of the primary and secondary coils respectively.

The function of the variable condensers at the transmitting and receiving stations is to electrically "tune" these stations. In the transmitting station of the system shown in Fig. 1, the so-called tuning is quite different in the case of the telephone and telegraph systems. In the case of the telegraph, the coupling of the coil I_1 and the capacities of both condensers at the transmitter are adjusted with reference to the production of a maximum current in the line wire, as indicated by a hot wire ammeter connected in the secondary circuit.[12] In the case of the telephone system, the coupling of the coil I_1 is made very small, and each of the condensers at the transmitting station is then independently adjusted to make the current in the circuit in which it is included a maximum, as indicated by hot wire ammeters connected in each circuit. The coupling of the transmitter coil is then increased till the tuning adjustment of one circuit interferes with the tuning adjustment of the other, and the circuits are readjusted, each by its own condenser, for a maximum of current in itelf. The reason for the radical difference in the tuning of the transmitter station in the telephone and telegraph systems may not be obvious. It is due to the fact that in the telegraph it is the actual amplitude of the high-frequency waves propagated along the line that determines the strength or loudness of the signals heard in the receiver, while in the telephone system it is the magnitude of the *variations in amplitude* of the high-frequency waves propagated along the line that determines the loudness of the received speech. Moreover, in the case of the telegraph the loudness of the received signal is the sole object, while in the case of the telephone a still more important requirement is excellence in the quality or articulation of the transmitted speech. In the case of the telegraph, therefore, the adjustment of the transmitter station is such as to produce the maximum amplitude of the transmitted waves, while in the case of the telephone system the adjustment is primarily adapted to securing the best quality of the transmitted speech, and, incidentally, to produce the maximum *variation in amplitude* of the transmitted waves.

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[12] J. S. Stone on the "Maximum Current in the Secondary of a Transformer," *Physical Review,* vol. xxxii, No. 4, April, 1911.

P. O. Pedersen, *Uber. d. Empfang kontin. elektromagnet Wellen usw.* in the *Jahrbuch der Drahlosen Telegraphie und Telephonie,* 1910. Also *Resonanz in gekoppelten Schwingungskreisen* in the same journal for 1911.

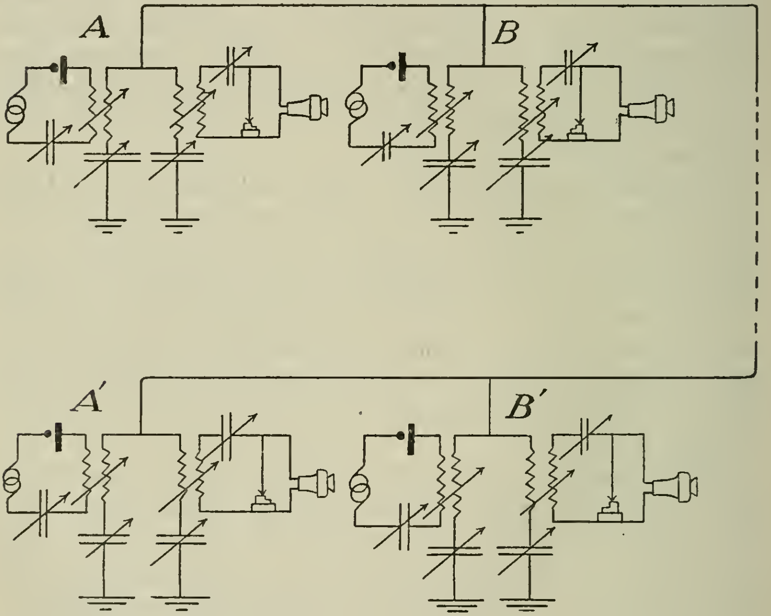
Thus, by loosely coupling the primary and secondary circuits at the transmitter and then adjusting the primary circuit for a maximum of current, the reactance of the primary is made zero and the impedance of the primary is reduced to practically the mere resistance of that circuit, so that the resistance of the telephone transmitter becomes practically the sole factor in determining the primary current. Obviously this makes the variations in the amplitude of the high-frequency current due to variations in the resistance of the telephone transmitter a maximum, and, on the other hand, telephone engineers will realize that the elimination, so far as possible, of all reactance and resistance except that of the telephone transmitter, from the primary circuit at the transmitter station, is a prerequisite to good quality or articulation of the transmitted speech.

At the receiving station of the system shown in Fig. 1, whether it be used as a telegraph or a telephone system, the tuning of both primary and secondary is directed merely to the production of a maximum current in the secondary circuit, and for this tuning the telephone receiver is used as the indicating device, since the current at the receiving station is not sufficient to permit of the use of a hot wire ammeter. A sensitive galvanometer may sometimes be used with advantage for tuning purposes in place of the telephone receiver.

The system shown in Fig. 1 is obviously not of much general utility, since it provides only for one-way transmission. It is shown and described at some length merely because of its simplicity and to bring out the analogies and the distinguishing features of the new telegraph and the new telephone systems.

A duplex system of high-frequency telephony with two-way transmission for each station is shown in Fig. 2. Again, the simplest practicable arrangement is shown merely for the purposes of illustration, the more complex but more perfect multiplex station being shown in Fig. 3. Each station of the system shown in Fig. 2 combines a transmitter and receiver identical as to apparatus with the transmitter and receiver shown in Fig. 1, and differing from the simplex system of that figure only in the tuning of the stations. In this duplex system the frequency to which a given receiver is adjusted to respond is as remote as it can conveniently be made from that of the current generated by the transmitter at its own station and from that of the adjacent stations; thus if stations *A* and *A′* intercommunicate while stations *B* and *B′* intercommunicate, for transmitters of *A* and *B* might make use of frequencies of current of, say, 20,000 and 22,000 cycles per second respectively, while the transmitters of stations *A′* and *B′* made use of frequencies of 60,000 and 66,000 cycles per second respectively. Of course, then, the receivers of stations *A* and *B* would be adjusted to respond to currents of 60,000 and 66,000 cycles respectively, while the receivers of stations *A′* and *B′* would be adjusted to respond to currents of 20,000 and 22,000 cycles respectively.

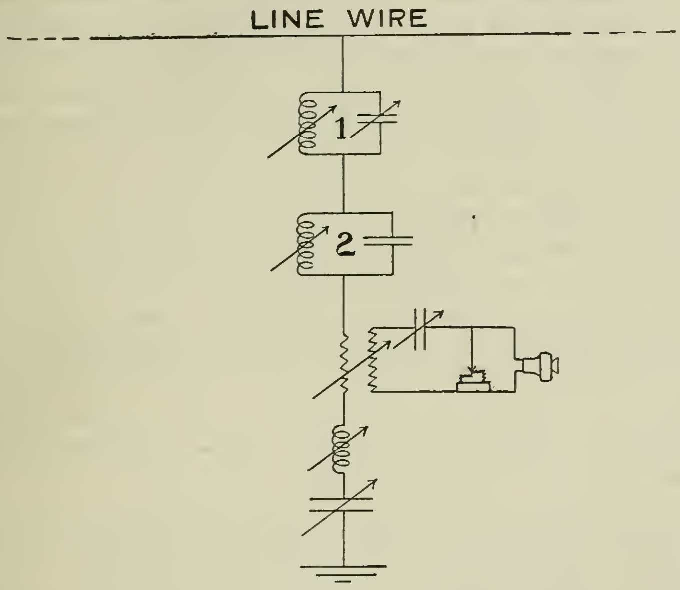
FIG. 2.



The tuning of the apparatus in the duplex system of Fig. 2, or even of the apparatus of a simplex system with two-way transmission, is not the same as that of the apparatus of the simplex system of Fig. 1, for the reason that in the duplex system and in the two-way transmission simplex system the new element of selectivity is required of the apparatus.

It might not at first seem necessary in a duplex or multiplex system to make the transmitter circuits selective, since the frequency at a transmitter is completely determined by the generator adjustment or the dynamo speed at that station, irrespective of any tuning of its circuits, but on closer examination it will be seen that were a transmitter branch circuit not tuned in such a way as to make it receptive of the current generated at that station and exclusive of currents of other frequencies, currents of all the frequencies used on the line would flow through it, and the variations of resistance of the telephone transmitter or manipulation of the telegraph key in the local circuit at that transmitter station would modify not only the amplitude of the current generated at that station, but would also modify the amplitude of the currents of other frequencies as well, and cause "cross talk" between stations on the line not intended to communicate with each other. Each branch, whether it be a transmitter or a receiver branch circuit, is so tuned that it has *per se*, that is, when disconnected from the line and short-circuited on itself, a minimum of impedance for currents of the frequency it is to select.

Fig. 3.



The simplest way to accomplish this tuning is to disconnect the branch and local circuit from the line, make the coupling of the coil very small and tune each circuit for a maximum of current by the adjustment of its own condenser. After this preliminary tuning, the coupling may then be increased to any desired extent and the final tuning for maximum current be easily effected. In the case of a receiving station it is in general desirable, in order to secure maximum selectivity, to employ a small coupling, and in tuning the apparatus of a receiving station the electromotive force is impressed upon the primary circuit. In a transmitter coil it is in general desirable to use a somewhat larger coupling, though maximum coupling is never advantageous, and in tuning a transmitter apparatus the electromotive force should be impressed on the primary for tuning the primary and on the secondary for tuning the secondary. The secondary branch of the transmitter is connected to the line while the primary is being tuned, and is short-circuited on the source of electromotive force [13] and the ammeter when being tuned itself. Of course, the tuning of a primary circuit disturbs the tuning of the associated secondary circuit, and *vice versa,* and the extent of this disturbance is roughly proportional to the square of the coupling coefficient between the circuits. As a result, the proper tuning of these stations is a matter of successive approximations, but with the small couplings which it is of advantage to use in order to secure a maximum degree of selectivity, two or three successive, alternate adjustments of the condensers in the primary and secondary circuits only are necessary, particularly after one has had some experience in tuning coupled circuits. As these tunings are of the nature of calibrations and are made once for all for a given frequency, they do not appear to constitute a valid objection to the system on the ground of their complexity or on the ground that they require special skill.

As already stated, the duplex system illustrated in Fig. 2 is a very simple form of the new system, but serves well to illustrate the general characteristics of a high-frequency multiplex system. It lacks, however, a feature the absence of which makes it necessary to choose remotely different frequencies for the use of adjacent transmitters and receivers, a fact which would, in many instances, place an arbitrary restriction on the use of wide ranges of frequencies and seriously limit the number of stations which could be simultaneously operated on a single line. The author has devised means which have overcome this difficulty, and three characteristic examples of this means are illustrated in Figs. 3, 4 and 5.

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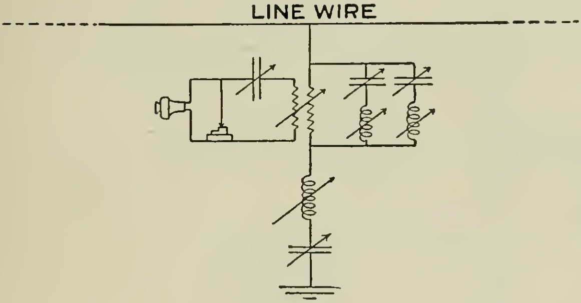
[13] The source of electromotive force must, of course, have its reactance neutralized by a separate condenser when it is used to tune a circuit from which it is to be removed after the tuning is completed.

In Fig. 3 the receiver circuit is shown alone, and it is to be noted that in the branch from the line wire there are two loop circuits, 1 and 2, each consisting simply of a condenser and a coil. These loop circuits are each made resonant *per se* to one of two frequencies, currents of which frequencies it is particularly desired to exclude from the receiver. Thus if this receiver were to be used at stations *A* or *B* of Fig. 2, its loop circuits 1 and 2 would be individually made resonant, each to one of the two frequencies generated by the transmitters of stations *A* and *B*, while if it were used at one of the stations *A′* or *B′*, its loop circuits would individually be made resonant each to one of the two frequencies generated at the transmitters of stations *A′* and *B′*. The effect of the presence of one of these looped resonant circuits in the receiver branch is practically to make the branch electrically opaque to currents of the frequency to which the loop is made resonant. So great may be made the impedance of such a loop circuit to high-frequency currents of that particular frequency to which it is attuned that it is possible to operate a system in which the receivers are thus protected against the currents from the transmitters at their own station and at adjacent

Fig. 4.



stations with less than 10 per cent. difference between the frequencies of the transmitters and receivers. If the apparent resistance presented by a loop circuit be called R' and the apparent reactance of the loop be called K', then

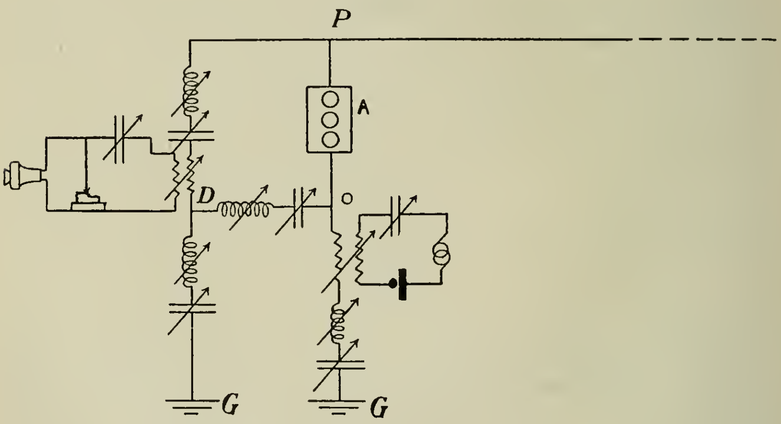
$$R' = \frac{R}{R^2 C^2 \omega^2 + (CL\omega^2 - 1)^2}$$

and

$$K' = -L\omega \frac{R^2 C/L + (CL\omega^2 - 1)}{R^2 C^2 \omega^2 + (CL\omega^2 - 1)^2},$$

where R and L are the resistance and inductance respectively of the coil, C is the capacity of the condenser and ω is the periodicity of the current or 2π times the frequency.

FIG. 5.



When the loop is resonant to the frequency of the current, $CL\omega^2 = 1$, making

$$R' = \frac{L}{CR}$$

and

$$K' = -\frac{1}{C\omega}$$

If in a given case the periodicity be 200,000, corresponding, therefore, to a frequency of 31,850, and if the inductance and resistance of the coil be five millihenrys and one ohm respectively, then the capacity will be 5×10^{-9} farads. In the case of such a loop, therefore, the apparent resistance of the loop to the currents it is designed to obstruct is one megohm, while the apparent reactance of the loop is one thousand ohms.

The presence of these loop resonant circuits in the receiver branches does not interfere with the tuning of the branches to the frequencies to which the latter are required to respond; in fact, the loop resonant circuits assist in such tuning, since for frequencies of currents higher than that, the passage of which a given loop circuit is adjusted to obstruct, the loop circuit presents an apparent capacity reactance and but small apparent resistance, while for frequencies of current lower than that, the passage of which it is adjusted to obstruct, the loop presents an apparent inductance reactance with but small apparent resistance. These apparent capacity and inductance reactances are balanced by the adjustable inductance and capacity reactance respectively of the branch so as to make the branch selectively receptive of currents of the desired frequency.

For currents of a periodicity ω_1 which is n times that to which the loop is made resonant, the apparent resistance and reactance of the loop are:

$$R' = \frac{R}{n^2R^2\frac{C}{L} + (n^2 - 1)^2}$$

and

$$K' = -nL\omega \frac{R^2\frac{C}{L} + n^2 - 1}{n^2R^2\frac{C}{L} + (n^2 - 1)^2}$$

In the case of the particular loop circuit just considered

$$R' = R / \left\{ 10^{-6}n^2 + (n^2 - 1)^2 \right\}$$

and

$$K' = -10^3 n \frac{10^{-6} + n^2 - 1}{10^{-6}n^2 + (n^2 - 1)^2}$$

If, therefore, in the case of the loop circuit in question, the branch containing it is made responsive to currents of a frequency 10 per cent. different from that of the current which the loop is adjusted to exclude, n is 1.1 or 0.9 and the apparent resistance of the loop to currents of this frequency is 22.7 or 27.7 ohms, depending on whether the frequency of the current to be excluded is lower or higher, respectively, than the frequency of that to which the branch is attuned to respond.

If the current to be excluded is of the higher frequency, then the apparent reactance of the loop in the branch is an inductance reactance of 4740 ohms, while if it be the lower frequency, the apparent reactance of the loop is a capacity reactance of 5240 ohms. In place of the loop circuits shown in Fig. 3, loop circuits inductively coupled with the receiver branch may be used.

The author has discussed in a more comprehensive manner the tuning of conductors containing looped circuits so as to exclude currents of one particular frequency while making the conductor selectively responsive to currents of another particular frequency in a paper read before the Electrical Section of the Canadian Society of Civil Engineers, March 9, 1905.[14]

The arrangement of receiving apparatus shown in Fig. 4 shunts the currents from the neighboring transmitters out of the receiver by means of branch circuits separately made resonant, one to each of the frequencies generated at adjacent or nearby stations.[15]

The arrangement of Fig. 5 is typical of the induction balance circuit which can be used to render a receiver irresponsive to the currents generated by the transmitter at the same station. In this arrangement, the branch *G O* is separately tuned to the transmitter frequency, while the branches *O D, P D* and *D G* are separately tuned to the receiver's frequency. The device *A* is one having adjustable resistance, inductance, and capacity, and whose vector impedance may be made to correspond to any scalar multiple of the vector impedance of the line measured from the point P outward.

The transmitter and receiver branches *O G* and *P D* respectively are conjugate, the vector product of the vector impedance of the branches *O P* and *D G* being equal to the vector product of the vector impedance of the branch *O D* and that of the line. Bridges of this kind must be balanced both for the resistances and for the reactances of the branches.[16]

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[14] See also U. S. Patents to Stone, Nos. 767,994 and 767,995.

[15] See U. S. Patents to Stone, Nos. 884,106, 884,107, 884,108, and 884,109.

[15] See "Electrical Papers" of Oliver Heaviside, vol. ii, pp. 33–38 and 366.

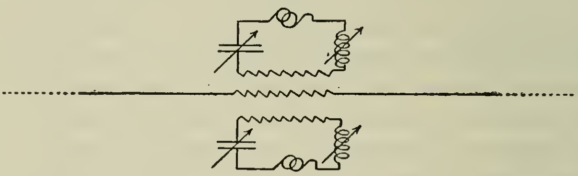
It is evident that when the conditions tending to produce interference in a receiver by a neighboring transmitter are exceptionally severe, the methods of freeing the receiver from such interference shown in Figs. 3 and 4 may be combined in the receiver without any difficulty. With a receiver so protected against "cross talk," the amount of energy of the current to be excluded may be millions of times greater than that of the current to be received and differ from the latter in frequency by but a few per cent. without causing the least interference.

A most important feature of both existing telegraphy and telephony is the centralization of the current supply, and this feature is, fortunately, most easily realized in the new high-frequency telegraphy and telephony. It brings the high-frequency generators, whether they be high-frequency dynamos or oscillators, under the constant supervision and care of a trained man at the central office. The author has devised several ways in which the centralization of the energy may be practically accomplished. Only two of these ways need be referred to here. In the first, the high-frequency generators are connected in series in the circuit at the central office, and each is shunted by a number of branch resonant circuits. Each branch circuit is separately made resonant to a different one of the several frequencies of the currents used on the line other than that of the current developed by the generator it shunts. Another practical mode of centralizing the energy is shown in Fig. 6. The several generators, each in a local circuit tuned to its own frequency, are brought into inductive relation with a transformer secondary in series or in parallel with the telephone or telegraph circuit. The generators in the centralized energy system develop higher potentials than those designed to be used at sub-stations, or else the voltage of the generator is stepped up to the desired voltage.

An allied arrangement, first suggested by Dr. Louis Duncan, contemplates using the high-frequency current only on trunk circuits. In this arrangement, which there is not space here to discuss in detail, a telegraph or telephone relay at the central office translates the telegraph or telephone message bearing current from the existing sub-station line equipped with its local or centralized battery supply into a high-frequency telegraph or telephone current on the trunk circuit, and conversely the high-frequency telegraph or telephone current on the trunk circuit is translated from that circuit to the local or sub-station battery circuit by a telegraph or telephone relay or by a rectifier. It is of interest to note that the most serious objections to the telephone relays lose their force in this application, because the telephone relay so used need not amplify the telephonic transmission, and it is in its function as an amplifier that the telephone relay has met conditions which have brought it into disrepute.

In this paper no more than a passing reference has been made to the extremely important fact that multiplex high-frequency telegraph and telephone systems may be superposed on existing telegraph and telephone circuits without bringing about the least mutual interference between the old and the new systems, and this subject and its important practical aspects will not be further dwelt upon here because it has received a fairly complete exposition at the hands of Major George O. Squier, both in his patents and in his paper before the American Institute of Electrical Engineers, to which references have been made. Only such features of high-frequency telegraphy and telephony as have not elsewhere been adequately brought out or discussed so as to make clear their bearing upon the future practical application of the propagation of high-frequency currents or electric waves along wires will be dwelt upon. This course, though it imparts to the paper a fragmentary character and an appearance of incompleteness, serves to keep it within reasonable bounds and should not diminish its utility, in view of the references given to other publications.

FIG. 6.



There is an element of every system of transmitting intelligence, namely, the *call* and its allied automatic circuit control mechanisms, which has been highly elaborated, particularly in the older system of telephony. In the new high-frequency telegraphy or telephony, when used by itself, either as a simplex or multiplex, the *call* and automatic circuit control mechanism system generally need not be different from that in use to-day in the older systems, but in lieu of this the call may be effected by a very flexible system of selective low-frequency electric signalling over the same line. In this selective signalling system, each of a number of stations on the same line is called by the use of a low-frequency alternating current of a different frequency thrown on the line, and the selection of the signalling current at the different stations called is effected by electrically resonant local circuits or branches at these stations, each attuned to the frequency of the particular alternating signalling current by which it is intended to be operated.[17]

The description of this system of selective signalling needs little amplification here, since it has long been known and is discussed in detail in the reference given, as well as in numerous patents to Professor Pupin, Messrs. Hutin & Leblanc, and to the author. There is just one new feature in the system, however, which should be mentioned, namely, that by the addition of rectifiers in the local branch signal receiving circuits the author believes that he has overcome the principal hindrance to the practical application of the system in the past. By this simple device the *call* at each station may be sounded by a vibrator bell of a uniform pattern. There seems little doubt that this extremely simple and flexible selective signalling system would long since have become popular for *party line selective calling* in the existing telephone system except for the fact that it demanded the use of some special, unsatisfactory, and unusual call device, different at each station.

When the high-frequency system is used in conjunction with, and on the same line as, the existing system of telegraphy and telephony, a separate high-frequency call or signalling system is preferably used. This call or signalling system is identical with the high-frequency telegraph system itself, except that it operates a local battery call device, such as a vibrator bell or buzzer, instead of operating a telephone receiver, and for this reason it is necessary that the calling current manifest more energy at a distant station than does the corresponding high-frequency telegraph or telephone current under similar conditions. To accomplish this purpose a relay of great sensibility and extreme sluggishness of action is used in conjunction with a rectifier in a tuned local circuit at the receiver station. To call the station, a high-frequency current of the same frequency as that to which the local circuit at the receiver containing the rectifier and relay is attuned is thrown upon the line and maintained thereon until the sluggish relay has time to respond and close the local battery circuit containing the vibrator bell or buzzer.

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[17] See record for Stone, Pupin, and Hutin & Leblanc in interference in the U. S. Patent Office No. 17,196.

The relay which the author has found to best meet this requirement of great sensibility through sluggishness of action, is of the Weston moving coil type. It has very high resistance and has an electro-magnet producing an extremely intense field in place of the permanent magnet of the usual Weston instrument. This method of effecting a call, which involves the integrating of the energy of the received current over a relatively long period of time by the use of a receiving device, extremely sluggish in its response, is imported from radio-telegraphy, where it was first used by the German company, the Gesellschaft für Drahtlose Telegraphie of Berlin. Experiments have not yet, so far as the author is aware, shown whether it is possible to operate this selective call over as great a length of line as it is possible to telephone or to telegraph at ordinary speed with a current of the same frequency, but the promise is good.

A great advantage enjoyed by the new high-frequency telephone system over the existing system is in the important particular of *distortion.* In the existing system of telephony, the currents as they are propagated along the line suffer a continual *attenuation* or a loss of amplitude, an effect to be minimized as far as possible. Still more harmful, however, in general, is the distortion of the telephone current which it engenders through the fact that the component alternating currents of different frequencies which make up the telephone current are unequally attenuated. Usually, therefore, long before a telephone current has been attenuated to a point at which it is too feeble to be of use, it has been so far distorted as to be incapable of producing intelligible speech at the receiver. In other words, considerably more attenuation than is now tolerable could be permitted in telephone systems were it not for the distortion that usually accompanies it.

In the new high-frequency system of telephony, *attenuation, though greater than in the older system, brings with it no distor-*

tion whatever. There is, in fact, in the transmission of a given message, but a single frequency of current involved, and therefore no unequal attenuation of components of different frequencies and no distortion.

Another signal advantage of the new high-frequency telephone system over the existing system lies in the *silent line*[18] which it enjoys. Were it not for the noisiness of the average telephone line in the existing system, telephone receivers of far greater sensibility could be used with advantage, and, furthermore, a much fainter transmitted speech would be easily understood and even prove more acceptable to the telephone subscriber than the louder transmission does on the average telephone line to-day. In the new telephone system, telephone receivers of several thousand ohms are used, having correspondingly greater sensibility than the low-resistance receivers in use in the existing telephone system.[19] Moreover, transmitted speech which is so faint that it would be completely swamped and ineffective on even a moderately noisy line is heard and understood against a background, as it were, of absolute silence.

The absence of distortion and the silent line of the new telephony remove the chief obstacle to the use of the telephonic amplifier at or near the receiving end of a long line to compensate for the weakening effects of attenuation on the current. In this connection it is to be noted that in the existing system, when a telephone current has been sufficiently attenuated in passing over a long line to require amplification, it is also so distorted, and so intermixed and confused with *line noise currents* which the amplifier would bring out or intensify that a telephone relay for amplification purposes, no matter how perfect it might be in itself, has by some engineers long been regarded as of little value. Another influence which has militated against the utility of amplifiers in telephony in the past is that for two-way transmission the amplifier has a persistent tendency to sing to itself in much the same manner and for much the same reason that a telephone receiver sings to its transmitter when it is held in front of the mouthpiece of the latter if the efficiency of the combination is sufficiently great. The greater the amplifying power of the telephone relay, the more persistent this tendency to sing to itself, and to overcome it resort has been had to so-called *telephone relay circuits,* which seek to exclude the current developed by the transmitter element of the amplifier from its receiver element. These *telephone relay circuits* are essentially induction balances in which the transmitter and receiver elements of the amplifier are in conjugate branches and the line wire forms one or more arms of the balance. In the case of an amplifier that really amplifies, the least change in the line conditions upsets the balance sufficiently to set the amplifier singing to itself and, even in the case of constant attention on the part of a skilled operator, this, at least temporarily, causes an interruption of service. In high-frequency telephony no such restraining conditions operate against the use of amplifiers for two-way transmission, since the current from the transmitter element and that directed to the receiver element are of different frequencies and the receiver element is placed in a branch or local circuit adjusted to exclude the current from the transmitter element, irrespective of the conditions of the line.

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[18] The receivers in the new system are not only unaffected by the usual *cross talk* or induction between adjacent telephone circuits, and by inductive disturbances generally, that so often cause confusing noises in the receivers of the existing telephone system, but they are, moreover, mute to their own transmitters. In other words, there is in the new system no so-called *side tone,* and the user of the system speaks as loudly as he pleases into his transmitter without deafening himself by hearing the sound of his own voice rasping in his own telephone receiver, as so often happens in the existing system.

[19] The sensitiveness of a telephone receiver is approximately proportional to the square root of the resistance of its windings. In connection with the centralized energy systems in the United States, telephone receivers of from 20 to 60 ohms are used. The telephone receivers employed in the new high-frequency system are of 2,000 ohms resistance.

Fig. 7 shows a typical arrangement of a telephone amplifier adapted for two-way transmission in a system of high-frequency telephony.[20] In it the transmitters and receivers are the same as those already shown and described, and at the amplifier station *C*, the transmitter and receiver elements are the same as the transmitters and receivers shown at *A* and *B*. In such a system the transmitters at both stations *A* and *B* develop currents of the same frequency, this frequency being that of the current to which the receiver element of the amplifier is responsive, while the receivers at both stations *A* and *B* are selective of currents of another frequency, this second frequency being that of the current developed by the transmitter element of the amplifier.

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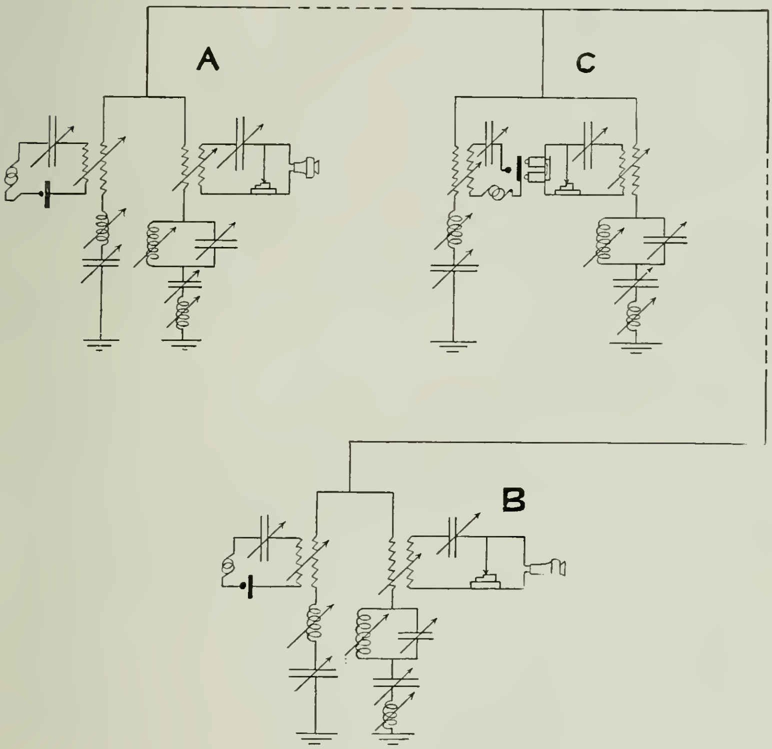
[20] See U. S. Patents to J. S. Stone, Nos. 717,515 and 717,467, both of Dec. 30, 1902.

It is not the intention here to imply that the existing telephone amplifiers are all that could be desired, but the author believes that he is not alone among telephone engineers in holding the view that the disrepute into which these instruments have fallen is due in a very large measure to the disabilities which they suffer when an attempt is made to fit them into the existing system of telephony, a system to which, as has here been shown, the telephone amplifier is ill adapted.[21]

FIG. 7.



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[21] A new telephone relay amplifier has recently been discovered which is entirely electrical in its action, having no moving parts whatever. It is productive of great amplification, and it appears to do this without appreciably distorting the telephone current.

The most serious obstacle to the successful use of the new high-frequency telegraph and telephone is undoubtedly the excessive attenuation or progressive weakening of its current as it flows along the line, particularly in cable circuits, and unless countervailing or remedial conditions can be found, the use of these high-frequency systems must be very materially restricted through being confined to relatively short lines.

The average frequency of the ordinary telephone current is about 800 cycles per second, but the highest harmonics range between 4,000 and 5,000 cycles, and it has been found that it is necessary, for the complete clearness of articulation of the transmitted speech, to conserve harmonics up to about 1,500 cycles.[22] The highest useful frequency in ordinary telephony is, therefore, about one-tenth of the lowest frequency which Major Squier's experiments seem to indicate as possibly practicable for the new telephony, and about one-seventieth of the highest frequency regarded as practicable by Major Squier for the new system. In making comparisons of the attenuation in the old and new systems these ratios should be borne in mind.

Since in the new system of telephony a greater current is thrown on the line than in the existing system, and since, further, a receiver of very much greater sensibility is employed, evidently a considerably greater attenuation of the current of the system is permissible than could be tolerated in the old system, and when, further, the absence of noise, the absence of *distortion,* the absence of *side tone,* and the absence of reflection of energy from the receiving end of the line are taken into consideration, it seems conservative to estimate that the maximum practical permissible *attenuation length* in the new telephony is 6.9, as compared with 4.6 in the existing system. An example of how this affects the range of transmission of the new system may perhaps be best gathered from a concrete example, and for this purpose an open-wire telephone line construction will be chosen which is of a type in most common use in the United States for transmission to distances up to 450 miles. This line is of the two-wire or so-called *metallic circuit* type, in which the wires are of hard-drawn copper 0.104 inch in diameter, and are separated on the cross-arms by a distance of 12 inches. Assuming for this line an insulation resistance of one megohm per mile, the ratio of the attenuation constant for currents of 1,500 and 100,000 cycles per second respectively is very closely 3, and, other things being equal, this would mean that the new system could not be used to transmit speech over more than 150 miles of such a circuit. On the basis of an attenuation length of 6.9, however, it would seem that practical transmission of speech by the new system could be had over a length of 225 miles of this circuit. The disparity between the distances to which unaided transmission may be had by the existing and the new system is somewhat greater in the case of open-wire circuits of larger than of smaller wire, and this disparity is, in general, greater in the case of cable circuits than in the case of open-wire circuits.

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[22] See B. S. Cohen, *Phil. Mag.,* Sept., 1908; also *Proc. Phys. Soc. London,* vol. xxi.

Even if no effective means be found to extend the range of the new high-frequency telephony, few will seriously contend that there is no practical gain to be realized in making use of a 450-mile circuit as it is at present used and further simultaneously employing it in two sections, each 225 miles in length, for the multiple transmission of, say, forty-two messages, twenty-one on each section.[23]

Before leaving the subject of the attenuation of high-frequency waves propagated along conductors, it is worth while to note that the expressions for the attenuation constant and the wave length or wave speed on copper open-wire circuits is much simpler than it is in the case of waves of lower frequencies, and the reader will find that he may easily compute the attenuation and wave length or wave speed in the case of any given circuit.

The complete expression for the attenuation constant per centimetre of a uniform unloaded circuit is

$$\alpha = \left[\tfrac{1}{2} \left\{ (R^2 + L^2\omega^2)^{\frac{1}{2}} (S^2 + C^2\omega^2)^{\frac{1}{2}} + (RS - CL\omega^2) \right\} \right]^{\frac{1}{2}}$$

in which expression R, L, C, and S are the resistance, inductance, capacity, and leakage conductance respectively, all in absolute elec-

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[23] The number of stations which can be used in any given case is the nearest whole number to

$$1 + \frac{0.82393}{\log_{10}(1 + \Delta)}$$

where 100Δ is the least percentage difference permissible between frequencies. The number of stations assumed in the above example is on the basis of a 10 per cent. difference between the frequencies.

tromagnetic units per centimetre, and ω is the periodicity or 2n times the frequency of the waves.

Making use of the relation

$$CL = \frac{1}{v^2} + \vartheta C,$$

in which v is 3×10^{10}, writing a for $\frac{R}{L\omega}$ and b for $\frac{S}{C\omega}$, the expression for α becomes

$$\alpha = \left[\frac{(1 + \vartheta C v^2)\omega^2}{2v^2} \left\{ (1 + a^2 + b^2 + a^2 b^2) \right\} \right]^{1/2}$$

But $a^2\ b^2$ is negligible compared to unity, $a^2 + b^2$ is small compared to unity, and so also is $\vartheta\ C\ v^2$. Consequently, by the use of the approximation

$$(1 + \delta)^{\frac{1}{2}} = 1 + \frac{\delta}{2}, \text{ where } \delta \text{ is small compared to unity,}$$

the expression for α reduces to

$$\alpha = \frac{\omega}{2v}\left(1 + \vartheta\frac{Cv^2}{2}\right)\left(a + b\right)$$

The complete expression for the wave length in centimetres is

$$\lambda = \frac{2\pi}{\beta}$$

where

$$\beta = \left[\frac{1}{2}\left\{(R^2 + L^2\omega^2)^{\frac{1}{2}}(S^2 + C^2\omega^2)^{\frac{1}{2}} - (RS - CL\omega^2)\right\}\right]^{\frac{1}{2}}$$

For high frequencies this reduces to

$$\beta = \frac{\omega}{v}\left(1 + \vartheta\ \frac{Cv^2}{2}\right)\left\{1 + \frac{1}{8}\left(a - b\right)\right\}$$

The velocity of propagation of the waves is $V = \frac{\omega}{\beta}$ in centimetres per second.

To express the attenuation constant a and the wave length constant β in terms of miles instead of centimetres they may be multiplied by 160,934.4, the number of centimetres in a mile.

In the above expressions

$$C = \frac{1}{4v^2 \log_\varepsilon \frac{d}{r}}$$

where d is the distance between the two wires of the circuit in any units and r is the radius of the wire in the same units.

$$L = \frac{1}{Cv^2} + \vartheta$$

$$R = R_{\omega=0}(1 + \frac{k^2}{48} - \frac{k^4}{2880} - - - - - -$$

where $R_{\omega=0}$ is the resistance of the wire to low-frequency or direct currents and

$$k = \frac{nc^2}{\rho}$$

where n is the frequency of the waves, c is the circumference of the wire, and ρ is the resistivity of the material of the wire in absolute electromagnetic units per centimetre.[3] For hard drawn copper at 75° F., ρ may be taken as 1748.

When k is large, say at least equal to 6, then the simpler expression

$$R = R_{\omega=0}\left(\frac{1}{2}\sqrt{k}\right)$$

may be used.

When k is less than 8,

$$\vartheta = 1 - \frac{k^2}{96} + \frac{13k^4}{69120} - - - - -$$

and when k is greater than 8,

$$\vartheta = \frac{2}{\sqrt{k}}$$

One megohm per mile makes $S = 6.214 \times 10^{-21}$ absolute electromagnetic units per centimetre.[3]

Except for the development of these new simplified expressions for α and β, the mathematical theory of the subject of electric wave propagation on conductors has been so exhaustively treated elsewhere as to need no restatement here.

The reader who wishes to pursue this mathematical theory for the sake of its intrinsic beauty and interest can do no better than to consult the works of the great master of the subject, Mr. Oliver Heaviside, whose collected papers are entitled "Electrical Papers" and "Electromagnetic Theory." He will find these works to be a rich mine of information on the subject, and he will also find that the similarity of these books to a mine extends to the method by which he will have to extract his information from them. A much simpler and more concise though more restricted and utilitarian discussion of the subject is to be found in Prof. J. A. Fleming's book, entitled "The Propagation of Electric Currents in Telephone and Telegraph Conductors," which brings out, perhaps more clearly than any other of his numerous writings, Professor Fleming's unusual powers of simple and clear exposition of technical subjects of exceptional complexity—a quality the more to be admired because of its rarity in English technical and scientific writings.

In the existing system of telephony, when it is necessary to diminish the attenuation on a line without increasing the size of the wire used or the separation between the wires, resort is had to methods of diminishing the attenuation constant by diminishing the quantity a, this being done by adding inductance to the line without producing a proportionate increase in its resistance. A circuit so treated is said to be "loaded" with inductance and is called a "loaded" circuit. Two methods have been used. In one the added inductance is uniformly distributed along the line and is secured by wrapping the insulated wire with a winding of iron wire. This method of loading cables has found favor in Germany and Holland.[24] In England, France, and the United States the only method of loading telephone lines used is by means of a system variously ascribed to M. I Pupin,[25] to G. A. Campbell,[26] to Sylvanus P. Thompson,[27] and last, but by no means least, to A. Vaschy.[28] In this *multi-patratus* system of loading lines inductance coils having time constants $\frac{L_1}{R_1}$ larger than the time constant per unit length of the unloaded line $\frac{L}{R}$ are introduced in the circuit at equal intervals, small compared to one-half the wave length of the highest frequency component of the telephone current to be conserved in transmission.

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[24] "Moderne Telefonkabler," by Mr. C. E. Krarup, Elektroteknikeren, Dec. 10, 1904.

"On Submarine Cables for Long-distance Telephone Circuits," by Major O'Meara, *Jour. Inst. Elect. Eng.*, London, Nov., 1910.

U. S. Patent to J. S. Stone, No. 578,275, of March 2, 1897.

[25] "Propagation of Long Electrical Waves," by M. I. Pupin, Trans. A.I.E.E., March, 1899.

"Wave Transmission over Non-uniform Cables and Long-distance Air Lines," by M. I. Pupin, Trans. A.I.E.E., May, 1900.

The method of loading lines by uniformly distributed added ferric inductance would seem, on its face, to be available for the high-frequency systems of telegraphy and telephony, but it suffers from several disadvantages. In the first place, it is ill adapted for open-wire circuits; in the second place, it renders cables excessively heavy and bulky; in the third place, it is impossible to predetermine the attenuation constant of such a circuit, and, in the fourth place, there is evidence tending to show that when a cable so loaded is used in connection with high-frequency currents the dissipation of energy due to hysteresis in the iron wrapping will largely, if not wholly, compensate the beneficial effects of the increased inductance of the circuit.[29]

The use of the second system of loading lines would seem to be precluded by the expense involved. The number of loading coils used would have to be about 70 times as great for the 100,000 frequency current of the new system as is now used on the basis of approximately 4.5 coils per wave length for a current of 1,500 frequency.

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[26] Records for Pupin & Campbell in interference in the U. S. Patent Office No. 20,699, also *Phil. Mag.*, vol. v, p. 319, March, 1903.

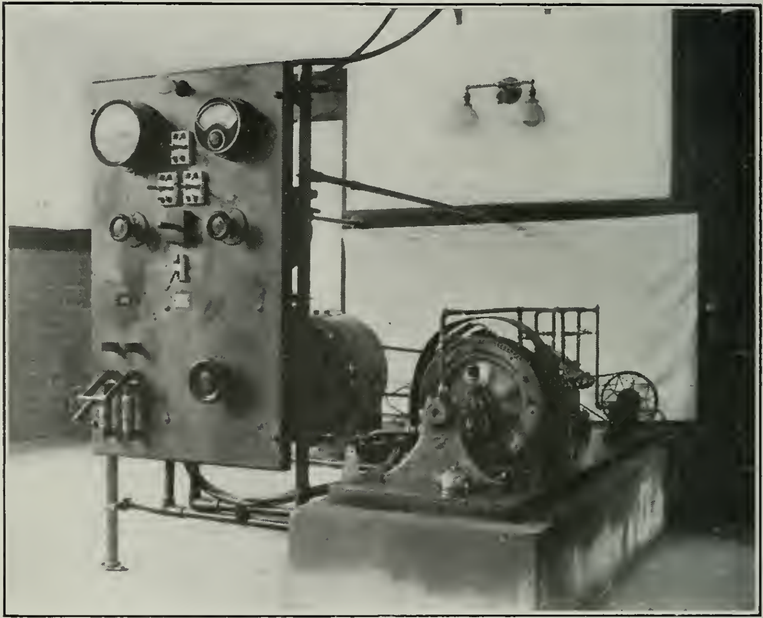
[27] "Ocean Telephony," by S. P. Thompson, *Trans. Int. Elect. Congress,* 1893; also English Patents Nos. 13,064 and 15,217 of 1893.

[28] A. Vaschy's numerous mathematical discussions bearing upon this subject are to be found in *Annales Telegraphique* 1888, '89, in his *Électricité et Magnétisme,* and in *L'Éclairage Électrique* 1897, and elsewhere.

[29] The effect of dissipation of energy in the iron wire wrapping is to increase the effective or apparent resistance of the copper conductor. Thus in the Seeland-Samso-Jutland cable, which is about 20 nautical miles in length and is uniformly loaded by iron wire wrapping, the inductance is increased 868 per cent., and the apparent resistance to a current of 900 frequency is 5 per cent. greater than to a direct current. What proportion of this increase in the effective resistance of the copper conductor is due to hysteresis loss in the iron wrapping is as yet undetermined. If it were wholly due to hysteresis, then it would be approximately 550 per cent. at 100,000 frequency, but probably not more than one-half of the increase in effective resistance of the copper conductor is due to this cause. The remainder is due to the unequal distribution or the imperfect penetration of the alternating current into the copper wire.

Since, for equal degree of loading of the line in the new and the old systems, the inductance of the coils used for currents of 100,000 frequency would be but one-seventieth of that of the coils used in the old system, it might at first glance seem as if the coils would be correspondingly cheaper, and that, consequently, the disparity in the cost of loading the line in the two systems would result chiefly from the greater cost of labor in installing the more numerous coils in the case of the new system. But this conclusion is not justified, because the time constant of the coils in the case of the new system must be as great as in the older system, and the bulk, weight, and cost of coils depend far more on their time constants than on their inductances.

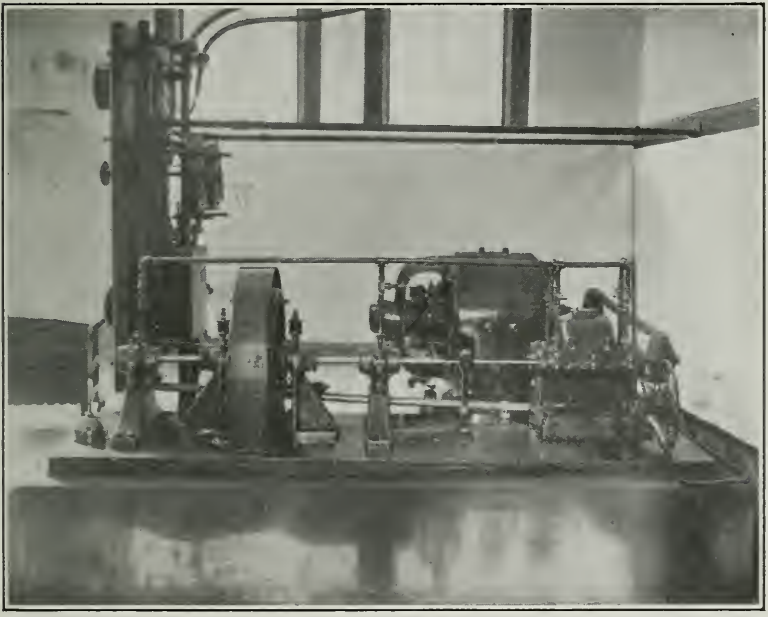
FIG. 8.



Alexandarson high-frequency dynamo and switchboard.

So far from these systems of loading lines with inductance holding out hope of improving the range of high-frequency telegraphy and telephony, the very fact that many trunk circuits are already loaded with coils for the improvement of the existing system bids fair to interfere with the extension of the high-frequency system to these lines. To apply the high-frequency system to a line which is loaded for the existing system it becomes necessary to shunt the loading coils by condensers which shall act practically as a short circuit to the loading coils for the high-frequency currents and which shall act practically as an inappreciable shunt to them for the low-frequency telephone current. The cost and inconvenience of this would probably not offset the advantages to be gained from the increased effective number of circuits secured, but, however this may be, it is a fact that, so far as can be seen at present, *the high-frequency system will not be applied to more*

FIG 9.

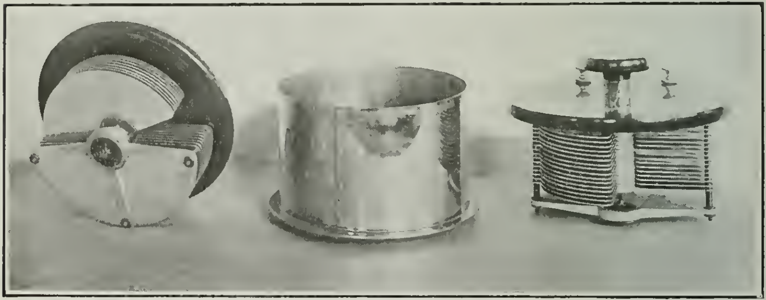


The Alexandarson high-frequency two-kilowatt dynamo, showing the driving electric motor and Delaval gear.

than one circuit on a pole line or in a cable, and this one circuit could be left unloaded without great loss.

The reason that but one circuit on a pole line or in a cable, as these are at present constructed, can with advantage be multipled by the new high-frequency system is that the transposition of the wires on the existing pole lines and the twisting of the pairs of wires in the existing cables are adapted to give workable freedom from cross talk between the circuits with the existing frequency of current, the existing strength of current at the transmitter, and the existing sensitiveness of the receiver. When all these quantities are augmented, as they are in the high-frequency system, energy will flow from one circuit to another in the same cable or on the same pole line to an extent that will preclude the use of the same frequency of current for the transmission of different messages on different circuits in the same cable or on the same pole line.

FIG. 10.



Type of adjustable condenser used in the new system.

In the latter half of this paper the new system has been treated more particularly in reference to its application to trunk lines, but the promise it holds out of a twenty-party sub-station telephone line with not only selective calling but selective or multiple speech transmission may to some, in itself, seem sufficient to justify the money that has been expended and the patient, unrequited human effort that has been freely given in bringing the new system to its present state of development, and to warrant the further effort and expenditures which will be necessary before it can yield its full service to society.

AN OUTLINE OF THE THEORY OF BALLOONING.[1]

BY

MAJOR SAMUEL REBER,

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In the endeavor to condense the outline of the theory of ballooning into the compass of one lecture, the writer has perforce been compelled to omit a number of interesting propositions and to state the principles involved in the briefest possible manner. He hopes, however, the following may lead to a further study of this most interesting subject and that the principles set forth will assist the class in understanding the reasons for the various operations involved in the manœuvring of a balloon.

In this discussion the constants of the international standard atmosphere as expressed in English units have been employed. The international standard atmosphere is the atmosphere which, at sea level, in latitude 45, at a temperature of 32° F., gives a pressure of 2,111 pounds per square foot (14.66 pounds per square inch or 29.921 inches of mercury) where no vapor of water is present. Under these conditions a cubic foot of air weighs 0.080529 pound. The following notation has been adopted and the subscript zero is employed to indicate that the value of the quantity to which it is attached is taken at sea level or at the starting point of the balloon:

V, the volume of the balloon in cubic feet.

z, the height of balloon in feet above sea level, or starting point.

a, the weight of a cubic foot of air.

b, the weight of a cubic foot of the gas filling the balloon.

d, the density of the gas in terms of air as unity.

p, the pressure of air or gas.

v, the volume of air or gas.

f_g, the ascensional force of the gas in pounds.

f, the starting ballast in pounds.

F, the total ascensional force of the gas filling the balloon, in pounds.

Φ, the ascensional force of the balloon, in pounds.

w, the solid weight of the balloon, in pounds.

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[1] Lecture delivered at the Army Signal Station, Fort Omaha, May 27, 1912.

From the standpoint of the balloonist the atmosphere is a perfect mixture of oxygen and nitrogen in the proportion of one to four, with a trace of carbonic acid gas and a varying amount of vapor of water. It behaves as a perfect gas and obeys the laws of Mariotte and Charles as expressed by the formula

$$pv = 57T \qquad (1)$$

in which T is the absolute temperature of the atmosphere on the Fahrenheit scale and 57 is the gas constant for the standard atmosphere.

The pressure and volume of the atmosphere at any temperature t can be expressed in terms of a standard pressure $p_\circ$ and volume $v_\circ$ at 32° F., as follows:

$$pv = p_\circ v_\circ \left(1 - 0.002039\,[t - 32°]\right) \qquad (2)$$

The weight of a cubic foot of air varies with the geographical position of the place, with its elevation above the sea level, with the temperature and pressure, and with the amount of vapor of water in the air. The variation in the weight due to the latitude and elevation above sea level is given by the following:

$$a = a_\circ\,(1 - 0.0026 \cos 2\varphi - 0.0000003z) \qquad (3)$$

in which ϕ is the latitude and z the elevation in feet above sea level. For any heights that a balloon can reach, the altitude term can be considered as negligible. This is also true of the latitude term, as in passing from latitude 45 to the poles or the equator the weight of a cubic foot of air is increased or diminished only by 26 parts in 10,000.

If the temperature remain constant the law of Mariotte applies and the weight of a cubic foot of air, due to the variations in the pressure of the atmosphere, is expressed as follows:

$$a = \frac{p}{2111}\,a_\circ = \frac{h}{29.921}\,a_\circ \qquad (4)$$

h being the corrected height of the mercury column or the reading of the aneroid. The change in weight due to extreme variations in barometric pressure can hardly exceed 5 per cent. of the standard value.

If the pressure remain the same the change in weight due to difference in temperature is given by Charles's law as follows:

$$a = a_0 (1 - 0.002039 [t - 32°]) \qquad (5)$$

in which t is the temperature of the atmosphere expressed in degrees Fahrenheit. The variation in weight due to extreme temperature variations in the vicinity of Fort Leavenworth and Fort Omaha can amount to as much as 20 per cent.

Due to the pressure of vapor of water in the air, the true pressure of the air is the difference between the total pressure and the tension of the vapor of water present. If e is the tension of the vapor of water, the weight of the unit volume of air is

$$a = a_0 \frac{p - e}{2111}$$

The weight of the vapor of water is $\frac{a_0 de}{2111}$ and the combined weight of the air and the vapor of water is

$$a = \frac{a_0}{2111} (p - e [1 - d]).$$

Taking the density of the vapor of water as 0.622, the above reduces to the following:

$$a = \frac{a_0 (p - 0.378e)}{2111} \qquad (6)$$

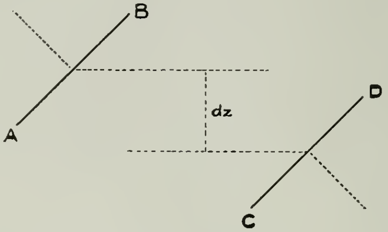
The weight of a cubic foot of air, taking into consideration the effect of variation of atmospheric pressure and temperature and the amount of vapor of water present, is as follows:

$$a = 0.08 \frac{(p - 0.378e)}{2111} (1 - .002[t - 32°]) \qquad (7)$$

At Fort Omaha, where the mean height of the barometer is 28.837, the mean temperature 50° F., and the mean vapor tension 0.3 inch of mercury, the mean weight of a cubic foot of air is 0.07457 pound.

For any two small surfaces *AB CD* (Fig. 1), immersed in a gaseous mass in equilibrium and subjected to the force of gravity alone, Pascal's principle states that each surface will be acted upon at its centre of gravity by a pressure which is normal to it and independent of its direction, and that the difference of pressure between the two surfaces is equal to the weight of a unit volume of gas multiplied by the vertical distance between the centres of gravity of the surfaces. If dp represent the difference in pressure between these surfaces and dz the

FIG. 1.



vertical distance between their centres of gravity, we have from the above principle:

$$dp = adz. \tag{8}$$

This principle can be applied at once to determine the law governing the variation of atmospheric pressure with height under the assumption that the weight of a unit volume of air at any altitude is proportional to the pressure at that altitude, or

$$\frac{p_0}{a_0} = \frac{p}{a} = A \tag{9}$$

this assumption implying that the ratio is independent of the height. Taking the values for the standard atmosphere, we have as a value for the constant

$$A = \frac{2111}{.080529} = 26217,$$

or, in other words, if the density of the air is uniform throughout the column, the height of a homogeneous atmosphere would be 26,217 feet.

In Fig. 2, let H_0 H_0 represent sea level, H H a plane z feet above it, here the pressure is p, and H' H' another horizontal plane above and infinitely near the plane H H. The difference in pressure between these two planes is

$$dp = -adz \tag{10}$$

the minus sign indicating that the pressure is acting downward. Using the values in equation 9, we have

$$dz = -A \frac{dp}{p} \qquad (11)$$

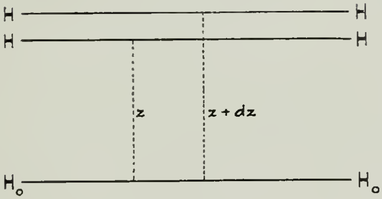
$$dz = -A \frac{da}{a} \qquad (12)$$

Integrating, we have

$$z = -A \int_{p}^{p_o} \frac{dp}{p} = A\,(\log_e p_o - \log_e p) = A \log_e \frac{p_o}{p} \qquad (13)$$

$$z = -A \int_{a}^{a_o} \frac{da}{a} = A\,(\log_e a_o - \log_e a) = A \log_e \frac{a_o}{a} \qquad (14)$$

FIG. 2.



Equations 13 and 14 may be written as follows:

$$\frac{p}{p_o} = e^{-\frac{z}{A}} = 1 - \frac{z}{A} \qquad (15)$$

$$\frac{a}{a_o} = e^{-\frac{z}{A}} = 1 - \frac{z}{A} \qquad (16)$$

The approximate value of $1 - \frac{z}{A}$ is obtained by developing $e^{-\frac{z}{A}}$ in a series and neglecting all the terms containing $\frac{z}{A}$ higher than the first power, which can be done for moderate heights. Substituting the value of A as given above and passing to common logarithms, equations 13 and 14 reduce to the following:

$$z = 60368 \log \frac{p_o}{p} \qquad (17)$$

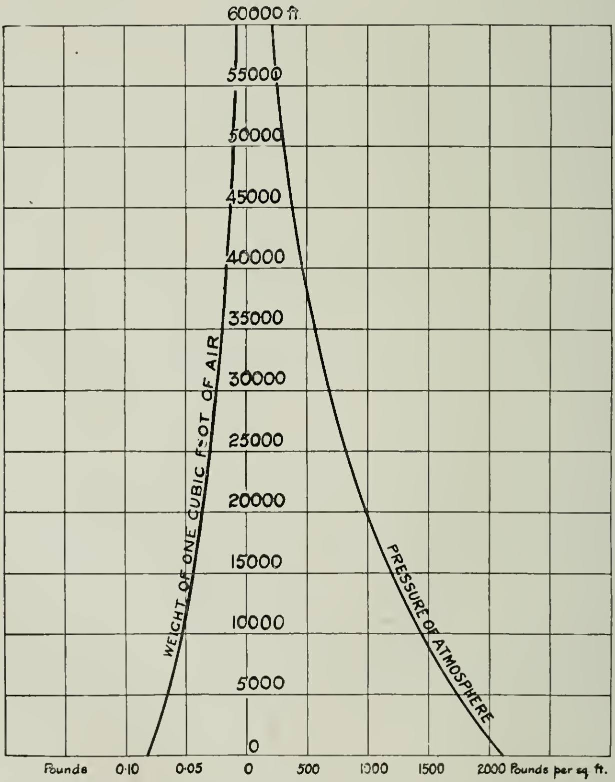
$$z = 60368 \log \frac{a_o}{p} \qquad (18)$$

The above formulæ, due to Halley, show that as the height increases in arithmetical progression, the pressure of the atmosphere and the weight of the unit volume decrease in geometrical progression. At a height of 60,368 feet, or 11.43 miles, the pressure is 0.1 that of the surface, and at a height of 22.86 miles the pressure is 0.01 of that of the surface. In general terms for

$$z = 60368\, n,\ p = \frac{1}{10^n}\, p_0.$$

Fig. 3 shows the variation of atmospheric pressure and weight of the unit of volume of air computed from the foregoing formulæ. Both coal gas and hydrogen, the gases employed in ballooning, obey the same laws as air, and the weights of a unit

FIG. 3.



volume of each of these gases can be computed in exactly the same way as that of the air.

The following table gives the values of z for all values of the ratio $\frac{p_0}{p}$ from 1 to 1,259:

TABLE I

$\frac{p_0}{p}$	z									
	0	1	2	3	4	5	6	7	8	9
1.00	0	26	52	79	105	131	157	184	210	236
1.01	262	285	312	338	364	390	417	443	469	492
1.02	518	545	571	597	623	646	673	699	725	751
1.03	774	800	826	850	876	902	928	951	978	1004
1.04	1027	1053	1079	1102	1129	1156	1178	1204	1230	1253
1.05	1279	1302	1328	1354	1378	1404	1427	1453	1479	1502
1.06	1528	1552	1578	1601	1627	1650	1676	1699	1726	1749
1.07	1775	1798	1824	1847	1870	1896	1919	1945	1968	1994
1.08	2018	2041	2067	2090	2116	2139	2162	2188	2211	2234
1.09	2260	2283	2306	2330	2356	2379	2405	2428	2451	2474
1.10	2500	2523	2546	2572	2595	2618	2644	2667	2690	2713
1.11	2736	2759	2782	2808	2831	2854	2877	2900	2923	2946
1.12	2972	2995	3018	3041	3064	3087	3110	3133	3159	3182
1.13	3202	3228	3251	3274	3297	3320	3343	3366	3389	3412
1.14	3435	3458	3481	3504	3527	3550	3573	3596	3619	3642
1.15	3665	3688	3711	3734	3757	3777	3800	3823	3846	3869
1.16	3891	3914	3937	3960	3983	4006	4026	4049	4072	4095
1.17	4117	4140	4163	4186	4209	4232	4255	4275	4298	4321
1.18	4341	4361	4384	4407	4429	4452	4472	4495	4518	4538
1.19	4560	4583	4606	4626	4649	4672	4692	4715	4737	4757
1.20	4780	4803	4823	4846	4869	4888	4911	4934	4954	4977
1.21	5000	5023	5043	5066	5089	5112	5135	5155	5178	5198
1.22	5213	5236	5259	5279	5290	5321	5338	5364	5384	5407
1.23	5426	5449	5469	5492	5512	5535	5555	5577	5597	5620
1.24	5640	5660	5683	5703	5723	5745	5768	5788	5808	5828
1.25	5850	5873	5893	5913	5936	5955	5975	5995	6017	6037

An example will show the use of this table. Required the difference in altitude between two stations when the barometer reading at the lower station is 29.921 and the upper station 28.640. The ratio of the readings is 1.045, and, entering the table with this ratio, we find the difference in altitude to be 1,156 feet. (NOTE.—If the readings are obtained by use of the mercurial barometer, these readings should be corrected for temperature; if obtained by an aneroid barometer, no correction is necessary for temperature.)

In the foregoing discussion the temperature has been considered uniform throughout the air column and no account has been taken of the geographical position, the effect of the change of the force of gravity due to altitude, or the hydroscopic state of the atmosphere. Under ordinary conditions the thermometer in this latitude falls as the height increases at an average rate of about three degrees per thousand feet. Owing to the motion of vertical currents in the air, the distribution of heat is very unequal, and it is practically impossible to predict in advance the temperature that will be encountered at any elevation above the surface of the ground. While Halley's formula may be considered sufficiently accurate for practical purposes up to about 5,000 feet, for heights greater than this the effects of the temperature variation and force of gravity due to the elevation of the lower station above sea level and the hydroscopic state of the atmosphere must be taken into consideration. The limits of this paper do not permit the presentation of La Place's solution of the problem. It is to be noted that La Place's formula, in a very convenient shape, is to be found in the Smithsonian Meteorological Tables, which should be used when a considerable degree of accuracy is desired.

The ascensional force or the lifting power of a gas is the difference between the weight of a unit volume of air and a unit volume of gas. Calling f_g the ascensional force of the gas, we have

$$f_g = a - b = a(1 - d) \tag{19}$$

If V is the volume of a balloon completely full of gas whose ascensional force is f_g, the total ascensional force of the gas or the total weight that the gas can lift is

$$F = Vf_g = V(a - b) = Va(1 - d) = V(a_0 - b_0)\frac{p}{p_0} = F_0\frac{p}{p_0} \tag{20}$$

It is evident from equation 20 that for balloons of equal volume, the balloon filled with the lighter gas will have the greater total ascensional force or will lift the greater weight. The two gases used in ballooning are hydrogen and coal gas, whose densities can, for practical purposes, be assumed as 0.12 and 0.42 respectively. The ascensional force f_g of hydrogen becomes 0.071 lb. and for coal gas 0.044 lb. The total ascensional force of a balloon of V capacity at start, when filled with hydrogen is

$$F_0 = 0.071\ V \qquad (21)$$

and for coal gas

$$F_0 = 0.046\ V \qquad (22)$$

No matter how impermeable the envelope of a balloon may be, there is always the greatest difficulty in keeping it in the air for any considerable period of time, owing to its vertical instability. This instability is due to the variations in the temperature and pressure at different heights, alternations of sun and shade due to clouds, to passage through warmer or colder strata, to rain, dew or snow, causing expansion or contraction of the gas, or changes in the weight of the balloon. When in the air a balloon acts like a submerged submarine boat which sinks to the bottom or rises to the surface of the water unless held in position by the use of ballast. If the boat in its forward movement encounters warmer or colder strata in the water, it sinks or rises unless water ballast is pumped out or in, and is never for any length of time in a state of equilibrium between the bottom and the surface of the water. A balloon is at rest only on the surface of the earth or in a zone of equilibrium.

A balloon can be in one or two states, either completely or partially inflated. In the former state its volume is constant and its weight variable, while in the latter its weight is constant and its volume variable. When a completely inflated balloon ascends, the atmospheric pressure diminishes and the gas in the envelope expands, escaping through the sleeve of the appendix, which is always open. The envelope remains full and the volume constant so long as the balloon is rising or is in a zone of equilibrium. When the balloon begins to descend, the increase of pressure contracts the volume of the gas and, as the gas and air are at the same pressure, due to the open appendix, no air will enter the envelope which contracts, the weight of the gas remaining unchanged.

For a balloon of constant volume V, let W be equal to the weight of the air displaced. The ratio of the weight of the air displaced at sea level to that at any altitude will be

$$\frac{W_0}{W} = \frac{Va_0}{Va} = \frac{a_0}{a}$$

and by using equation 18 we have

$$z = 60368 \log \frac{W_0}{W} \qquad (23)$$

from which the weight of the air displaced at any altitude may be calculated. If the gas filling the balloon is at the same temperature as that of the air surrounding it, its variation of weight at different altitudes obeys the same law as the variation of the weight of the air. The total ascensional force of the gas filling the envelope is readily obtained by taking the difference between the weights of the air and the gas at various altitudes.

At the aëronautical station of the Signal Corps at Fort Omaha, two sizes of balloons are usually employed, one of 19,000 cubic feet and the other of 35,000 cubic feet capacity, and hydrogen is used to inflate them. The weights of the air displaced by these two sizes of balloons, together with the weights of the hydrogen and coal gas filling them, have been computed and are plotted in Fig. 4, together with the total ascensional force of the gas in each case.

When the balloon has been inflated, put on its feet, and the passengers, instruments and ballast are in the basket ready for ascension, the balloon is weighed; that is, ballast is either taken from or added to the basket until the balloon, when lifted from the ground, neither rises nor falls. If, after having been weighed, an amount of ballast is then put overboard, the balloon will rise until the total weight of the balloon is equal to the weight of the volume of air displaced, when, in accordance with the principle of Archimedes, its vertical motion will cease. It is then in a position or zone of equilibrium. The amount of ballast put overboard on starting is called the starting ballast or initial rupture of equilibrium. After the balloon has been weighed before starting, its total weight is then equal to the weight of the air displaced. The total weight of the balloon is made up of the weight of the gas filling the envelope and the solid weight of the balloon. The solid weight of the balloon is made up of the weight of all its parts, the weight of the passengers, instruments and impedimenta and ballast in the basket. and at start, in addition to these, the starting ballast.

The ascensional force of the balloon at any point is the difference between the weight of the air displaced by the balloon and the total weight of the balloon or the difference between the total ascensional force of the gas and the solid weight of the balloon. Calling the ascensional force of the balloon Φ and the solid weight w, we have

$$\Phi = F - w = F_0 \frac{p}{p_0} - w = F_0\left(1 - \frac{z}{A}\right) - w \qquad (24)$$

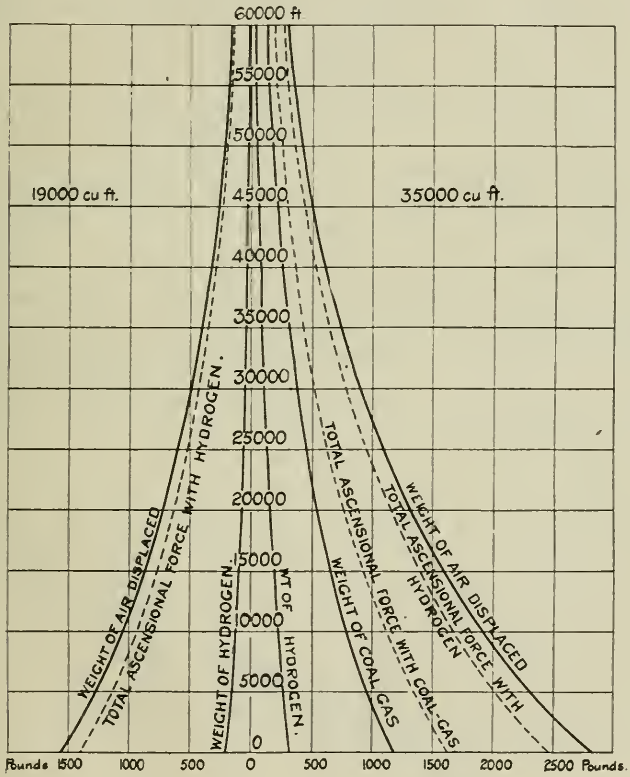
At start we have

$$f = F_0 - w \qquad (25)$$

f being the initial rupture of equilibrium.

When the balloon is in equilibrium, its ascensional force is zero, and we have from equation 24 the condition for equilibrium that the solid weight is equal to the total ascensional force of the gas or, what is the same thing, the total weight is equal to the volume of the air displaced.

FIG. 4.



The height of the zone of equilibrium which a balloon will reach with a given amount of starting ballast can be determined graphically by the method of Captain Barthes.

If the curve of the weight of the air displaced by the balloon and the curve of the total weight of the balloon for a given amount of starting ballast be plotted, and they intersect, their point of intersection gives the height of the position of equilibrium. In Fig. 5, the curves *AB*, the weight of the volume of air displaced, *NM*, the weight of the hydrogen filling the balloon, and *HI*, the total ascensional force of the hydrogen, are taken from Fig. 4. The curves *AC′* and *CD* represent the total weight of the balloon after having been weighed and after the amount of starting ballast *CA* has been put overboard. These are obtained by adding the curve *MN* to the vertical lines *F′E′* and *FE*, representing the solid weight of the balloon after weighing and after the starting ballast has been put overboard. It is to be observed that the total weight of the balloon for any given solid weight can be represented by a curve similar and parallel to *AC′* whose distance from the line *OZ* depends on its solid weight. The graphical effect of the expenditure of ballast is to move the curve *AC* parallel to itself nearer and nearer the axis of *Z*. The intersection of *CD* and *AB* at *G* is evidently the point of equilibrium, and the length of the line *GG′* gives the elevation of the position of equilibrium above the starting point. This height depends on the relative value of *CA*, or the amount of starting ballast. At the point *G*, the solid weight of the balloon is seen to be equal to the total ascensional force of the gas. The curve *LK*, the difference between *AG* and *CG*, gives the variation in the ascensional force of the balloon rising from *A* to *G*. The weight of the hydrogen lost in ascending to the point *G* is indicated by *G′C*, which can be computed as follows: Vb_0 is the weight of the gas at the start and Vb the weight of the gas at the point *G*; their difference $V(b_0 - b)$ is the loss, which by the use of equations 20 and 15 can be put in the form

$$\frac{F_0}{A} \cdot \frac{d}{1-d} \cdot z \qquad (26)$$

Applying this formula to the 19,000 and 35,000 cubic foot balloons filled with hydrogen, the loss of the hydrogen in pounds is 0.0007 z and 0.0015 z, respectively.

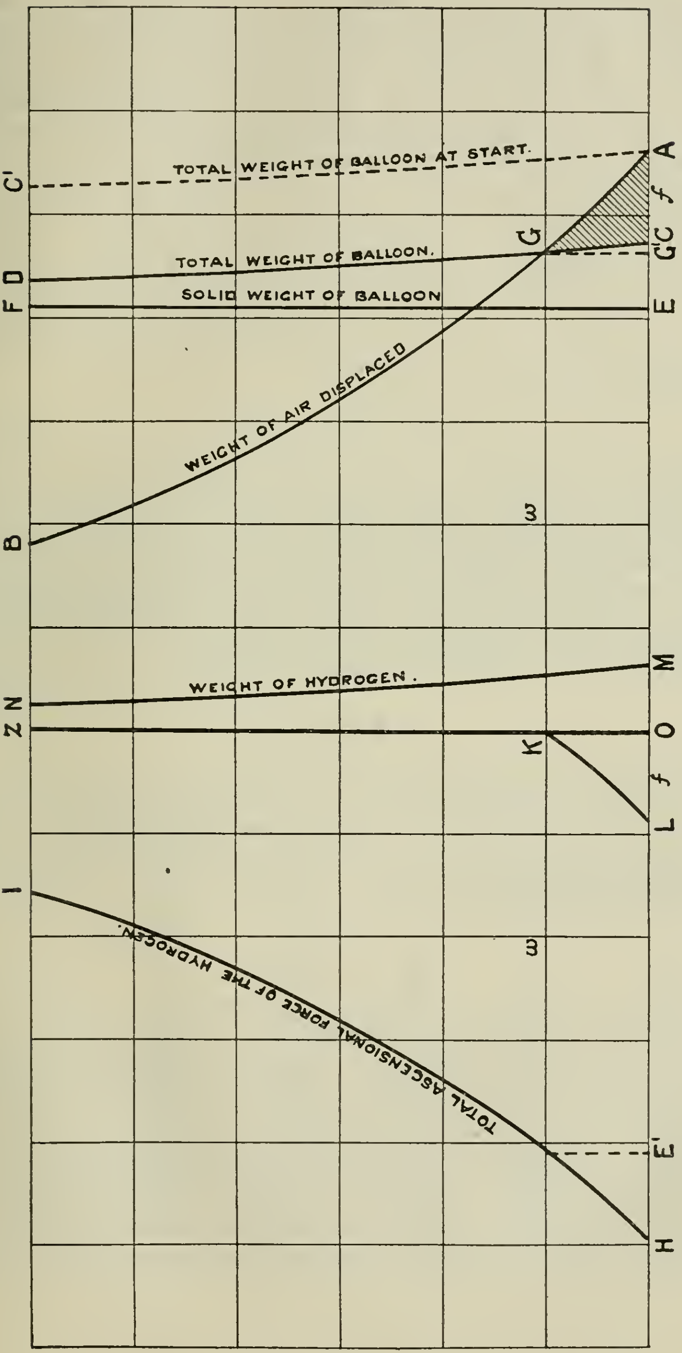

C'
F D
B
Z N
I
A
f
G C
E
M
O
L
f
K
G
E'
H
ω
ω
TOTAL WEIGHT OF BALLOON AT START.
TOTAL WEIGHT OF BALLOON.
SOLID WEIGHT OF BALLOON
WEIGHT OF AIR DISPLACED
WEIGHT OF HYDROGEN.
TOTAL ASCENSIONAL FORCE OF THE HYDROGEN.

FIG. 5.

Let us now obtain a formula which will determine the height to which a balloon will rise with a given expenditure of starting ballast. The expression for the ascensional force of a balloon at any point is given by the equation 24. Let us assume two points in the path of the balloon where the pressure of the air is p and p' respectively. The ascensional force at these points will be

$$\Phi = F_\circ \frac{p}{p_\circ} - w$$

$$\Phi' = F_\circ \frac{p'_\circ}{p} - w$$

and their difference is

$$\Phi - \Phi' = F_\circ \left(\frac{p}{p_\circ} - \frac{p'}{p_\circ} \right) \tag{27}$$

this latter expression giving the ascensional force necessary to raise the balloon from a point where the pressure is p to one where the pressure is p'. Let us now assume that at the point where the pressure is p' the balloon is in equilibrium and that it started from sea level with an initial rupture of equilibrium of f. Equation 27 will reduce to

$$f = F_\circ \left(1 - \frac{p'}{p_\circ} \right) \tag{28}$$

which gives a general expression showing the relation between the pressure at the position of equilibrium and the initial rupture of equilibrium at start from sea level. Equation 28 can be put in the following form:

$$\frac{f}{F_\circ} = \frac{p_\circ - p'}{p_\circ} \tag{29}$$

which gives us the general law that the diminution of the pressure of the air corresponding to a point of equilibrium is in the same ratio as the diminution of weight of the balloon. The use of formula 28 can be illustrated by an example. Let it be required to ascertain the amount of starting ballast that must be put overboard to cause a 19,000 cubic foot balloon filled with hydrogen to reach a position of equilibrium 4,800 feet above sea level. From equation 21 the total ascensional force of the hydrogen at sea level is 1350 pounds, and from Table I, for 4,800 feet the ratio $\frac{p'}{p_0}$ (the reciprocal of $\frac{p_0}{p'}$) is 0.83 and equation 28 becomes

$$f = 1350\,(1 - 0.83) - 230 \text{ lbs.},$$

or 5¾ sacks of ballast. (NOTE.—A sack of ballast weighs 40 pounds.) Equation 28 is not in convenient form for the direct calculation of the height of the position of equilibrium produced by the expenditure of a given amount of ballast, but can be transformed into the following:

$$z = A\,\frac{f}{F_0 - \frac{f}{2}} \qquad (30)$$

which is correct for all heights that a balloon can reach with safety. This formula has been used to compute the following ballast table for 19,000 and 35,000 cubic foot balloons filled with hydrogen. The table gives the heights above sea level of the positions of equilibrium for various amounts of starting ballast and the elevation of the zone of equilibrium caused by the expenditure of 20 pounds (½ sack) of ballast at the different heights.

TABLE II.

19,000-cubic-foot balloon filled with hydrogen.			35,000-cubic-foot balloon filled with hydrogen.		
Starting ballast, pounds.	Feet above sea level in zone of equilibrium	Rise in feet for 20 pounds of ballast expended.	Starting ballast, pounds.	Feet above sea level in zone of equilibrium.	Rise in feet for 20 pounds of ballast expended.
0	0	390	0	0	210
20	390	410	20	210	215
40	780	410	40	425	215
60	1190	410	60	640	215
80	1600	420	80	855	215
100	2020	420	100	1070	215
120	2440	430	120	1285	220
140	2870	430	140	1505	220
160	3300	440	160	1725	220
180	3740	450	180	1945	230
200	4190	460	200	2175	230
220	4650	460	220	2405	240
240	5110	470	240	2645	240
260	5580	470	260	2885	250

An example will illustrate the use of the foregoing table. The pilot of a 19,000 cubic foot hydrogen balloon in equilibrium at 1,550 feet is approaching a range of hills whose summit he discovers from his map is 2,500 feet above him. How much ballast should he put overboard to clear the range? To clear the range he should figure on ascending 2,700 feet, 200 feet being added as a margin of safety. The table shows that at a height of 1,600 feet 20 pounds of ballast will raise him 420 feet, and by simple proportion he ascertains that 128 pounds, or 3¼ sacks of ballast, will carry him to the desired altitude.

The ballast formula has been deduced under the supposition that the temperature of both the air and the gas is 32° F., and that the temperature does not change as the balloon rises. As a rule, the temperature of the air will fall as the balloon rises, and, moreover, the air and gas are usually at different temperatures; in fact, in some ascensions a difference of 50° F. has been found to exist between the temperature of the gas and that of the air. The values given in Table II are only approximate and should be corrected by the following considerations. When the temperature of the air and the gas remain the same, the height of the zone of equilibrium for a completely-filled balloon will be increased or diminished by 50 feet for each degree that the temperature of the air is diminished or increased, and this variation in the position of the zone of equilibrium is independent of the size and altitude of the balloon or the nature of the gas filling it. When the air and the gas are not at the same temperature, the zone of equilibrium is raised for each degree F. that the temperature of the gas exceeds that of the air by about 36 feet, if the balloon is filled with coal gas, and by about 6 feet if filled with hydrogen. A balloon filled with coal gas is about six times more sensitive to changes of temperature than one filled with hydrogen. A rise in the temperature of the gas over that of the air, caused, for example, by the passage from shadow to bright sunshine, will produce an elevation of the zone of equilibrium as though an amount of ballast had been put overboard, and the increase in altitude is independent of the volume of the balloon, but depends upon the nature of the gas used, it being greater for the denser gas.

Fig. 6 shows the result of expending ballast when a balloon is in equilibrium at different points above the ground.

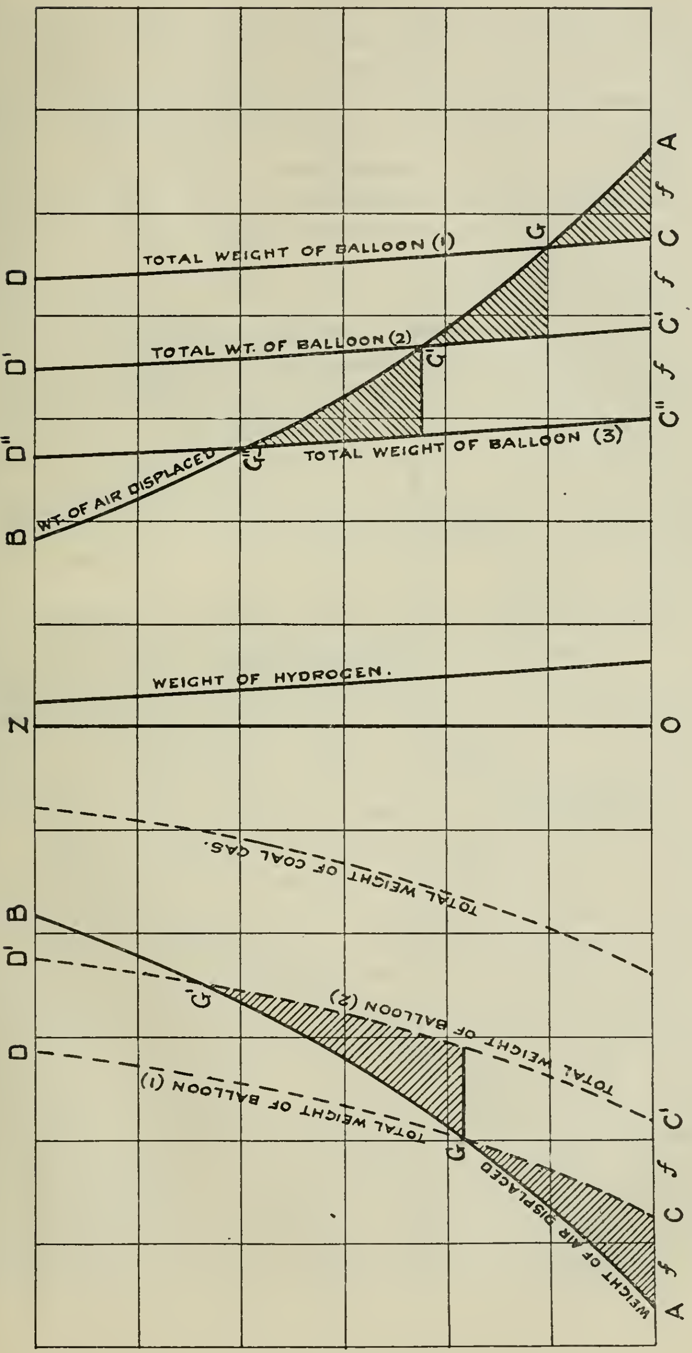

TOTAL WEIGHT OF BALLOON (1)
TOTAL WT. OF BALLOON (2)
TOTAL WEIGHT OF BALLOON (3)
WT. OF AIR DISPLACED
WEIGHT OF HYDROGEN.
TOTAL WEIGHT OF COAL GAS.
TOTAL WEIGHT OF BALLOON (2)
TOTAL WEIGHT OF BALLOON (1)
WEIGHT OF AIR DISPLACED
D
D'
D''
B
Z
B
D'
D
A
f
C
f
C'
f
C''
O
C'
f
C
f
A
G
G'
G''
G'
G

Fig. 6.

The curves to the right of the axis OZ refer to a balloon filled with hydrogen, and to the left one of similar volume filled with coal gas. G is the position of equilibrium reached by an expenditure of ballast CA. If at G the same amount of ballast $C'C$ be put overboard the new position of equilibrium will be at G', and at G', with an expenditure of ballast $C''C'$, equal to $C'C$, the new position of equilibrium is G''; and it is evident that for the same amount of ballast expended after the balloon is in a zone of equilibrium, the greater will be its rise, the higher its position above the surface of the earth. The relative positions of equilibrium for a balloon of the same volume filled with hydrogen and coal gas when the same amount of ballast has been expended are shown at G, G and G', G' to the right and left of the axis respectively. In each case it will be seen that the position of equilibrium for coal gas is higher than the corresponding position for hydrogen and gives a graphical explanation of the paradox that for balloons of equal volume for the same expenditure of ballast the balloon with the heavier gas will rise the greater distance.

Let us now take the case of a balloon of constant weight (Fig. 7), in which the envelope, instead of being entirely filled by gas, contains only a volume that weighs Fc, for which the weight of the air displaced by this volume is Oa. Let the balloon start with an initial rupture of equilibrium ca. It will rise and the gas in the envelope will expand until it completely fills the volume of the envelope. Until this point is reached, the weight of the gas filling the balloon remains constant. The weight of a unit volume of gas decreases directly as the pressure decreases, while the volume of the gas in the envelope increases directly as the pressure decreases. Their product, the weight of the gas in the envelope, is therefore constant. The same reasoning will show that the weight of the volume of air displaced by the envelope will likewise remain constant until the envelope has been entirely filled by the expansion of the gas. The point at which the envelope will be entirely filled by the expansion of the gas is evidently the intersection of the curve AB by the vertical line aa', which represents the weight of the air displaced while the balloon is partially inflated. The line cc' represents the solid weight of the balloon during this period in which the ascensional force of the balloon remains constant. As soon as the envelope

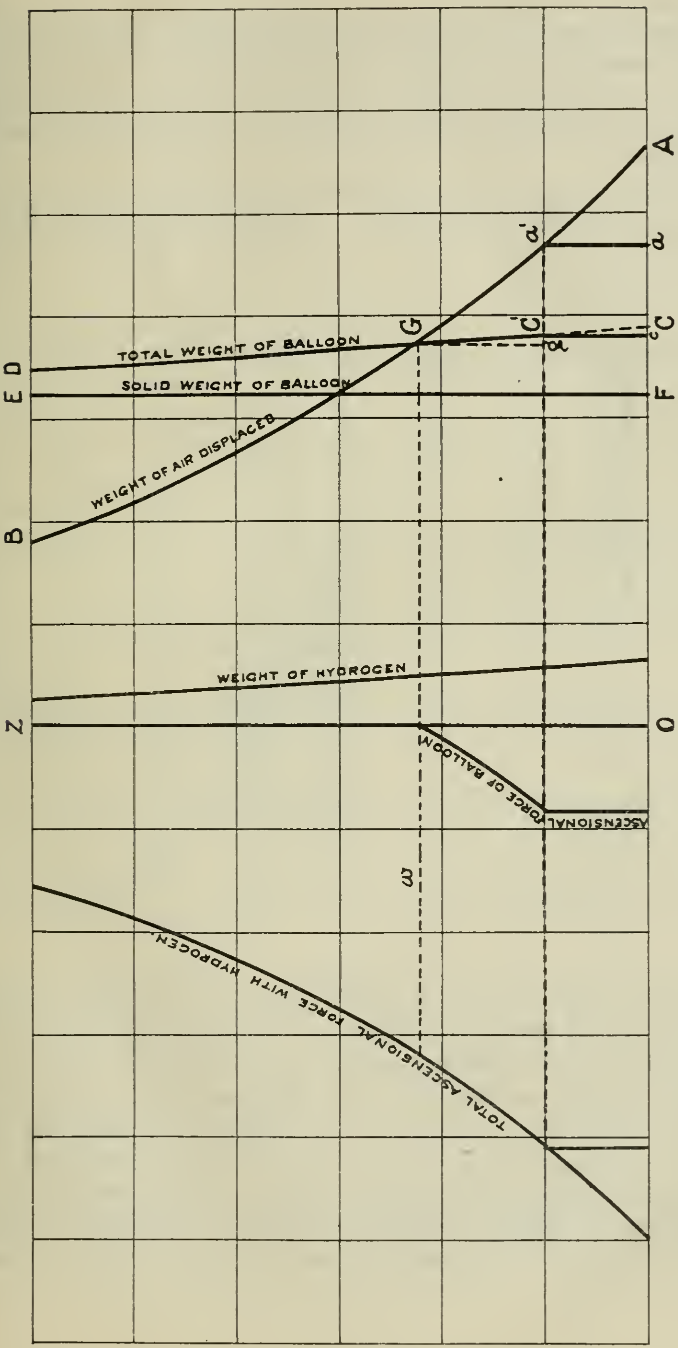
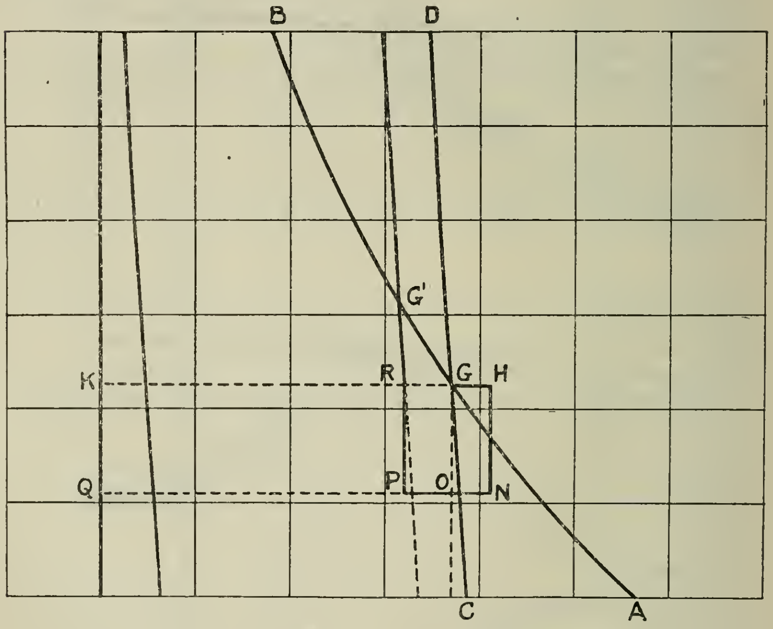

A
a'
a
C'
C
c
G
a
TOTAL WEIGHT OF BALLOON
E D
SOLID WEIGHT OF BALLOON
F
WEIGHT OF AIR DISPLACED
B
WEIGHT OF HYDROGEN
Z
O
FORCE OF BALLOON
ASCENSIONAL
ω
TOTAL ASCENSIONAL FORCE WITH HYDROGEN.

FIG. 7.

has been completely filled it will then be subjected to a rupture of equilibrium *cc′* and will rise until it loses a weight of gas *gc′* corresponding to the rupture of equilibrium *cc′* and the height of the zone of equilibrium is the same as if it had left the ground completely filled and with the same solid weight as when partially inflated.

Let the weight of the balloon in equilibrium at *G,* Fig. 8, be increased by a surcharge *HG.* Its total weight, *KH,* will now be greater than the air displaced, *KG,* and the balloon will be subjected to a negative ascensional force and will descend. As the balloon begins its descent, it will be partially deflated. Its weight and the weight of the air displaced, as has been shown before, will remain constant. The negative ascensional force will consequently be constant and the balloon will continue to fall until it reaches the ground, unless it is checked by an expenditure of ballast. If at any point *N* an amount of ballast *NO,* equal to the surcharge, be put overboard, the total weight

FIG. 8.



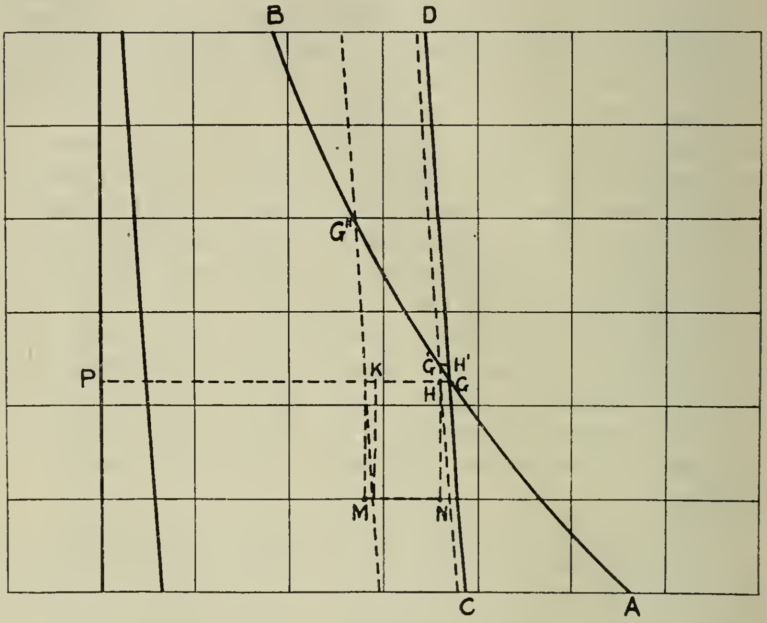
of the balloon and the weight of the air displaced are then equal, but, owing to its inertia, the balloon will continue its descent. If, however, an amount of ballast *PN*, greater than the surcharge, be put overboard, the total weight of the balloon, *PQ*, will now be less than the weight of the air displaced, *OQ*. The balloon will rise and, being only partially inflated, the ascensional force of the balloon, *PO*, will remain constant until the point *R* is reached, where the envelope is completely filled by the expansion of the gas. At the point *R* the balloon is completely filled and, being subjected to a rupture of equilibrium *RG*, will reach the new position of equilibrium *G′*. In general terms we may conclude that when a balloon descends (it is then partially inflated), the rupture of equilibrium is constant, and the balloon will fall to the ground unless its descent is checked by ballast, when it will rise to a new position of equilibrium which will be higher than the preceding one. During the course of an ascension a balloon has a constant tendency to descend, which must be overcome by the use of ballast. After each expenditure of ballast the position of equilibrium is higher than the preceding one, so that in general the balloon constantly increases its height above the surface of the earth during the entire course of an ascension.

The effect of allowing the gas to escape from the envelope by opening the valve is the same as that of a surcharge of weight and causes the balloon to descend. If, in Fig. 9, the balloon being in equilibrium at *G*, the valve is opened and an amount of gas whose weight is *HG* is allowed to escape, the weight of the volume of air *KG* corresponding to the volume of gas lost is greater than *HG* on account of the higher specific gravity of the air, and the total weight of the balloon, *PH*, is then greater than the weight of the air displaced, *PK*. The effect is as if the balloon were in equilibrium at *G′* and subjected to a surcharge of weight *G′ H′* equal to the weight of the volume of gas lost. If, after allowing a certain weight of gas to escape through the valve, the descent of the balloon is checked as at *N* by an amount of ballast *NM*, the new position of equilibrium *G″* is much higher.

Let us now briefly consider the velocity of motion of a balloon of constant volume, following the method of Colonel Renard. While ascending to moderate heights, the mass of the balloon can be considered constant, as the mass of the gas lost is a very small percentage of the total weight of the balloon.

The balloon is subjected to the action of two forces, one acting vertically upwards, the ascensional force of the balloon, and the other vertically downward, the resistance of the air. The resistance of the air can be expressed as follows:

FIG. 9.



$$R = kv^2$$

While the coefficient k varies with the height of the balloon, for practical purposes it can be considered constant and defined by the relation

$$k = 0.000424D^2$$

D being the diameter of the balloon in feet. If m is the mass of the balloon and v its velocity, the resultant force acting is

$$m\frac{dv}{dt} = \Phi - kv^2 \qquad (31)$$

From equations 24 and 25 we have

$$\Phi = f - \frac{F_\circ}{A} z$$

and placing this value in 31, we have

$$m \frac{dv}{dt} = f - \frac{F_\circ}{A} z - kv^2 \qquad (32)$$

as the general equation of the motion of the balloon. Equation 32 can easily be placed in the form of a lineal differential equation of the first degree whose integral is

$$kv^2 = f + \frac{mF_\circ}{2kA} - \frac{F_\circ}{A} z + Cke^{-\frac{2k}{m}z} \qquad (33)$$

Let $\beta = \frac{m}{2k}$ and introducing this into equation 33, we have the general expression

$$kv^2 = f + \frac{F_\circ}{A}\beta - \frac{F_\circ}{A} z + Cke^{-\frac{z}{\beta}} \qquad (34)$$

The constant of integration C is defined by the conditions at start, where both v and z are zero, and from 34

$$Ck = -\left(f + \frac{F_\circ}{A}\beta\right)$$

Substituting this in equation 34, the equation finally reduces to the form of

$$kv^2 = \left[f - \frac{F_\circ}{A}(z - \beta)\right] - \left(f + \frac{F_\circ}{A}\beta\right)e^{-\frac{z}{\beta}} \qquad (35)$$

which gives us a general expression for the velocity of the balloon at a point z feet above starting point. It is to be seen from 35 that the velocity depends on two terms, one lineal and the other exponential. To see the effect of the exponential term, let us take the case of a 19,000 foot hydrogen balloon starting with an initial rupture of equilibrium of 100 pounds. For this balloon $F^\circ = 1{,}350$ pounds, $\beta = 48$ feet, and $k = 0.464$. With these values we have the following table:

z	β	2β	3β	4β	5β
$e^{-\frac{z}{\beta}}$	0.368	0.135	0.50	0.018	0.0067
$f - \frac{F_\circ}{A}(z - \beta)$	100.0	98.5	97.0	95.5	93.0
$\left(f + \frac{F_\circ}{A}\beta\right)e^{-\frac{z}{\beta}}$	38.0	14.0	5.0	1.8	0.7
kv^2	62.0	84.5	92.0	93.7	92.3
v	11.56	13.49	14.07	14.21	14.08

From this table it is to be seen that the velocity rapidly increases to a maximum, and, after passing the maximum, slowly diminishes. The effect of the exponential term can be neglected after the balloon has reached a height of about 200 feet. Neglecting this term, the general expression for the velocity reduces to the form

$$kv^2 = f - \frac{F_\circ}{A} z + \frac{F_\circ}{A} \beta \tag{36}$$

If the value of kv^2 be substituted in equation 32, it will reduce to the following:

$$m \frac{dv}{dt} = - \frac{F_\circ}{A} \beta \tag{37}$$

from which it will be seen that during this period of the balloon's motion the resultant force acting on the balloon is constant and the velocity is uniformly retarded. The value of the term $\frac{F_\circ}{A}\beta$ is so small that it can be neglected, and we have

$$kv^2 = f - \frac{F_\circ}{A} z \tag{38}$$

or

$$v = \sqrt{\frac{f}{k} - \frac{F_\circ}{Ak} z} \tag{39}$$

as a general expression for the velocity of the balloon at the point z. If we neglect the second term under the radical, which can be done for all portions of the balloon's passage except the last, we have the expression

$$v' = \sqrt{\frac{f}{k}} \tag{40}$$

which is known as the velocity of regimen. From the above expressions it is to be seen that the motion of the balloon can be divided into three periods: the first, or starting period, in which the effect of the exponential term is felt, the velocity rapidly increasing to a maximum about 200 feet above the start; the second period, or the period of regimen, in which the motion of the balloon is uniformly retarded and its velocity approximately equal to the velocity of regimen and the resistance of the air almost equal to the ascensional force of the balloon; and the third or last period, in which the effect of the term $\frac{F_0}{Ak} z$ is felt. During this period the balloon comes slowly to rest.

Let us now investigate the time element. If z' be the altitude of the zone of equilibrium for a balloon whose total ascensional force is F_0 and initial rupture of equilibrium is f, we have from equation 28:

$$z' = A \frac{f}{F_0} \quad \text{or} \quad \frac{F_0}{A} = \frac{f}{z'} \tag{41}$$

Substituting this value in equation 38, we have

$$kv^2 = f\left(1 - \frac{z}{z'}\right) \tag{42}$$

Since $v = \frac{dz}{dt}$, equation 42 reduces to the form

$$\frac{dz}{dt} = \sqrt{\frac{f}{k}} \cdot \sqrt{1 - \frac{z}{z'}} = v' \sqrt{1 = \frac{z}{z'}} \tag{43}$$

or,

$$dt = \frac{1}{v'} \frac{dz}{\sqrt{1 - \frac{z}{z'}}} \tag{44}$$

and integrating, we have

$$t = -\frac{2z'}{v'}\sqrt{1 - \frac{z}{z'}} + C. \tag{45}$$

The constant of integration C is defined by the conditions at start, where both t and z are zero, and from 45 we have

$$C = \frac{2z'}{v'}$$

Substituting this value of C, equation 45 reduces to

$$t = \frac{2z'}{v'}\left(1 - \sqrt{1 - \frac{z}{z'}}\right) \tag{46}$$

which is the general expression for the time that the balloon will take to reach the altitude z. To ascertain the time required to reach a zone of equilibrium, put z equal to z' in the foregoing formula, which will reduce to

$$t = \frac{2z'}{v'} \tag{47}$$

Just before coming to rest the motion of the balloon is very slow. It is interesting to compare the time that it will take a balloon to travel a given height with the time that it takes to reach its position of equilibrium. Let us make z in equation 46 equal $\frac{9}{10}z'$, and we have

$$t' = \frac{2z'}{v'}\left(1 - \frac{1}{\sqrt{10}}\right) = 1.4\frac{z'}{v'} \tag{48}$$

from which we readily see that $\frac{t'}{t} = \frac{2}{3}$, approximately, or the time to travel the last tenth of the distance from the start to position of equilibrium is one-third of the total time of travel of the balloon.

The following table gives the height of the position of equilibrium, the velocity of regimen, the time required to reach the position of equilibrium in seconds, the time to travel $\frac{9}{10}$ of this course, together with the average velocity in feet per second, for both the 19,000 foot and 35,000 foot balloons:

TABLE III.

19000 FT. BALLOON.

Starting ballast, lbs.	Height of point of equilibrium.	Velocity of regimen, feet per second.	Time required to reach equilibrium, seconds.	Nine-tenths of course.	Average velocity feet per second.
	z	v'	t	t'	
20	390	6.5	120	85	4.6
40	780	9.2	170	120	6.5
60	1190	11.3	210	145	8.2
80	1600	13.1	245	170	9.4
100	2020	14.6	275	195	10.3
20	2440	16.0	305	210	11.6
40	2870	17.3	330	230	12.4
60	3300	18.5	355	250	13.2
80	3740	19.7	380	265	14.1
200	4190	20.7	405	280	15.0
20	4650	21.7	430	300	15.5
40	5110	22.7	450	315	16.0
		35000 FT. BALLOON.			
20	210	5.3	80	60	3.5
40	425	7.5	115	80	5.3
60	640	9.2	140	100	6.4
80	855	10.7	160	110	7.7
100	1070	11.9	180	125	8.6
20	1285	13.1	200	140	9.2
40	1505	14.1	215	150	10.0
60	1725	15.1	230	160	10.7
80	1945	16.0	245	170	11.4
200	2175	16.9	260	180	12.1
20	2405	17.7	270	190	12.7
40	2645	18.5	280	200	13.2

In case the balloon leaves the ground only partially inflated, the ascensional force remains constant until the envelope is completely filled by the expansion of the gas and is equal to the initial rupture of equilibrium. Under this condition the general equation of the motion of the balloon becomes

$$m\frac{dv'}{dt} = f - kv'^2 \qquad (49)$$

The integral of this equation is

$$Ce^{-\frac{z}{\beta}} = f - kv'^2 \qquad (50)$$

C being the constant of integration and $\beta = \frac{m}{2k}$

At start z' and v' are both zero and $C = f$. Introducing this value in equation 50, it reduces to the form of

$$v'^2 = \frac{f}{k}\left(l - e^{-\frac{z}{\beta}}\right) \qquad (51)$$

The value $e^{-\frac{z}{\beta}}$ rapidly approaches zero and in a very short time after starting we have $v' = \sqrt{\frac{f}{k}}$, the velocity of regimen.

For the partially-inflated balloon its motion can be divided into two periods: the first, or starting period, in which the velocity very quickly reaches the velocity of regimen; and the second period, in which the velocity is constant and equal to the velocity of regimen. If z' is the height of the zone of equilibrium, the time to reach this height can be expressed as follows:

$$t' = \frac{z}{v'} \qquad (52)$$

Comparing this expression with equation 47, we see that $t = 2t'$, or that a completely-inflated balloon requires double the time to reach the same zone of equilibrium that it would reach if partially inflated at start with the same rupture of equilibrium; in other words, for the same rupture of equilibrium, a completely-filled balloon moves more slowly than a partially-inflated one.

When descending, a balloon is only partially inflated, and its velocity, the velocity of regimen, is constant and depends on the surcharge or negative rupture of equilibrium to which it has been subjected. To make a perfectly safe landing, the velocity of regimen should not exceed six or seven feet per second, which for a 19,000 foot balloon corresponds to a rupture of equilibrium of 20 pounds. If the velocity of descent exceeds the above rate, the fall should be checked by putting overboard in succession about 2½ pounds of ballast for each 100-foot descent of the 19,000 foot balloon and 4½ pounds of ballast for the 35,000 foot balloon, until the motion has slowed down to the desired rate. The amount of ballast to be reserved for a descent depends upon a number of varying factors, such as the size of the balloon, difference in temperature between the ground and the point where balloon is situated, character of the ground, the velocity of surface wind, etc. It is impracticable to obtain a general expression covering the amount of ballast that should be reserved for the final descent. A safe rule, however, is to keep a full sack of ballast for the actual landing and to start the descent for landing when there remains in addition to this sack an amount of ballast equal to 15 pounds for each 1000 feet of elevation of the 19,000 foot balloon and 20 pounds for the 35,000 foot balloon.

The following important practical rules result from the foregoing discussion:

1. *The balloon should be completely inflated before departure.* The duration of an ascension, other things being equal, depends upon the amount of ballast that can be carried. When the balloon is completely filled, its lifting power is greater, and it will consequently take up more ballast than when partially inflated.

2. *The amount of ballast used at start should be as small as possible and just sufficient to clear obstacles.* Whenever ballast is put overboard, a position of equilibrium is reached, and, as the height of the position of equilibrium is constantly increasing during the progress of the ascension, the lower the initial position of equilibrium at start, the longer the balloon will remain at moderate heights.

3. *The tendency to descend should be checked as soon as possible.* When the balloon descends it acquires velocity, to overcome which requires a greater amount of ballast the greater the velocity. The new position of equilibrium to which the balloon will rise after its downward motion has been checked is higher than the former position of equilibrium and in proportion to the amount of ballast expended.

4. *Ascensional tendencies should never be checked.* To stop a balloon from rising, the valve must be opened and gas lost. This operation causes the balloon to descend. To check the descent, ballast must be expended with an increase in elevation, the object sought to be avoided. The pilot who begins to use his valve cannot remain long in the air.

5. *In landing, unless compelled by a rapid approach to the sea or a large body of water, the descent should be made slowly.* A sack of ballast should be reserved for the landing and the descent begun with a sufficient reserve of ballast.

A New Form of Silica. F. TUCAN. (*Centr. Min.,* 1912, 296.)—In a cave on the island of Brac there was found a secondary lime deposit which contained finely-divided silica, together with sodium chloride and traces of iron, aluminum, and magnesium. After the carbonates were dissolved in hydrochloric acid, the silica formed an impalpable, white dust. Mixed with water it formed a milky liquid which penetrated the best filter paper, and was insoluble even in concentrated alkalies, but soluble in concentrated sulphuric acid. Apparently this was a new form of silica. It is probably of secondary origin, having been precipitated from solution along with the calcium carbonate.

Patents in the United States. B. HERSTEIN. (*J. Ind. Eng. Chem.,* iv, 328.)—A patent for a chemical invention differs from other patents in that an identical product may be obtained by different processes of manufacture, so that infringement of a patented process is not readily detected. Manufacturers sometimes prefer, therefore, to keep new processes secret, and the difficulty is only partially met by the fact that the product itself, if new, may be claimed as the invention. Statistics show that the patent system does not stimulate chemical industries. During the decade 1900–1910, 4,068 patents were issued in the principal chemical industries, and only 38 per cent. of these were issued to persons resident in the United States, as against 88 per cent. for the whole of the patents on all subjects. More chemical patents are issued to German than to American inventors. Out of 1,738 patents in the classes "Carbon Compounds" and "Bleaching and Dyeing Processes," which form the most profitable branches of chemical industry, only 200 were issued to Americans, while 1,247 were issued to Germans, and 844 of these were assigned to four large companies which have an arrangement for the interchange of stock and division of profits, under an agreement lasting till 1954. The foreign inventor prefers to import the article, and is not compelled by law to manufacture in the United States; moreover, the tariff does not affect him, while domestic manufacture is prevented by patent. A compulsory working requirement would be of advantage to chemical industry. It is pointed out that as the result of the new compulsory working requirement in the United Kingdom, up to 1911, 50 foreign firms had begun, or were about to begin, manufacture in England, and that 7,000 hands would be employed; and in addition many licenses have been granted to English manufacturers. The industries affected are mainly in the chemical and allied groups. The fact that a patent is granted in the United States for a new product, apart from the process of manufacture, tends to prevent the introduction of new and better processes for making the same product. Where the patent is for the process only, there is a direct incentive to experiment with the object of obtaining the product by other and better methods.

THE EFFECT OF PIGMENTS UPON THE CONSTANTS OF LINSEED OIL.

BY

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When sealed packages of paints of the cheaper grades are opened after having been stored for a considerable length of time, there is occasionally observed a degree of hardness that renders application difficult. The user is generally at a loss to account for such a condition, inasmuch as the modern metal container is air-tight and has but little room for improvement. The cause of the hardening that has taken place may therefore be assumed to result from certain reactions between the different constituents of the paint. There can be no doubt but that certain kinds of pigments have some influence in the reactions that result in hardening, but the responsibility has been too often placed entirely with the pigment portion of paints. That the oil or vehicle part may have an even more profound relation to the trouble has not been given the consideration it deserves. In support of this statement there is presented herewith evidence of an important nature, in the form of results obtained from the tests described below.

Nearly two years ago the writer carefully prepared a series of paints from various well-known pigments, using as a grinding medium a standard vehicle of pure linseed oil containing neither drier nor thinner of any type. The amount of oil used with each pigment was sufficient to bring the paints in every case to a relative viscosity or body, which was somewhat heavier than is ordinarily used in the application of paints to wooden or metal surfaces. These paints, after preparation, were carefully placed in friction-top tin containers. They were moved about occasionally and were subjected to shipment by freight on two occasions, finally remaining on a shelf in the writer's laboratory for nearly a year previous to examination. Upon removing the lids from the cans there was evidenced, by the appearance of some of the paints, a considerable change of a chemical nature. The writer, attributing the change that had taken place to a form of saponification, or rather hydrolysis, as such action may be properly termed in the case of paints, was impressed with the opportunity of examining the oil content of the paints, in order to determine whether any marked change had occurred in the constants of the pure linseed oil which was used in their grinding. Fortunately, there was on record the analysis of the oil which had been used for this purpose. The paints were therefore placed individually in two-quart glass jars with a large quantity of a solvent mixture made of 90° benzol and 86° petroleum ether. After the pigment content of the paint had settled out by gravity, the solvent containing the oil in solution was removed by a syphon and subjected to distillation. The temperature of distillation was kept at a point sufficiently high to remove the low boiling point solvent, but not high enough to affect the oil residue. The usual method of oil examination was then followed, many of the determinations being made in duplicate. The results of these tests are given below.

RESULTS OF EXAMINATION OF OILS EXTRACTED FROM PAINTS.

Analysis of oil used in grinding and thinning paints:

Specific gravity	.932
Ash	.190%
Iodine No.	181.
Acid value	2.5

TEST NO. I.

Zinc Oxide.

Condition on Opening.—Paint in excellent condition. Very soft. Some oil of light color floating on top. After extraction with solvent the oil contained fine white zinc of a colloidal nature, which separated out only after several days' standing.

Analysis of extracted oil:

Specific gravity	.9237
Ash	0.36% (white)
Iodine No.	161.
Acid value	3.5

TEST NO. 2.

Corroded White Lead (Basic Carbonate-White Lead).

Condition on Opening.—Paint had thick, wrinkled skin on top, but was in very fair condition. Oil, after extraction, was light colored and clear.

Analysis of oil:

Specific gravity	.9372
Ash	1.149% (light yellow)
Iodine No.	157.5
Acid value	8.6

TEST NO. 3.

Leaded Zinc.

Condition on Opening.—Paint in very good condition. Considerable oil floating on top. Oil, after extraction, was somewhat cloudy, but cleared up after settling for twenty-four hours.

Analysis of oil:

Specific gravity	.9389
Ash	.922% (white)
Iodine No.	157.4
Acid value	5.7

TEST NO. 4.

Corroded White Lead (Basic Carbonate-White Lead)	50%
Zinc oxide	40%
Barytes	10%
	100%

Condition on Opening.—Paint in excellent condition. Some oil floating on top.

Analysis of oil:

Specific gravity	......
Ash	.674% (light yellow)
Iodine No.	154.1
Acid value	6.7

TEST NO. 5.

Sublimed white lead (basic sulphate-white lead)	60%
Zinc oxide	40%
	100%

Condition on Opening.—Paint in excellent condition. Some oil floating on top.

Analysis of oil:

Specific gravity	.9334
Ash	.626% (white)
Iodine No.	157.8
Acid value	5.6

TEST NO. 6.

Barytes (Barium Sulphate).

Condition on Opening.—Paint settled to a considerable extent. Much clear oil floating on top.

Analysis of oil:

Specific gravity	.9325
Ash	.212% (light)
Iodine No.	160.6
Acid value	3.5

TEST NO. 7.

Silica.

Condition on Opening.—Heavy, viscous oil, resembling a varnish, was floating on a partly-settled mass of pigment. After extraction, the oil held some finely-divided pigment in suspension for some time.

Analysis of oil:

Specific gravity	.9465
Ash	.204% (light)
Iodine No.	149.2
Acid value	8.7

TEST NO. 8.

American Vermilion (Basic Chromate of Lead).

Condition on Opening.—Pigment settled very hard. Oil, after extraction, was dark, but clear.

Analysis of oil:

Specific gravity	.939
Ash	1.271% (yellow)
Iodine No.	156.7
Acid value	8.3

TEST NO. 9.

Red Lead.

Condition on Opening.—Pigment settled very hard. A thick, gelatinous oil floating on top of pigment. Oil, after extraction, was dark brown in color.

Analysis of oil:

Specific gravity	....
Ash	15.56% (light red)
Iodine No.	135.4
Acid value	19.2

TEST NO. 10.

Iron Oxide.

Condition on Opening.—In excellent condition. Very soft, smooth paste. After extraction, the oil was clear, but of a dark red color.

Analysis of oil:

Specific gravity	.9457
Ash	.456% (red)
Iodine No.	156.3
Acid value	8.6

TEST NO. 11.

Carbon Black.

Condition on Opening.—Thin, wrinkled skin on surface. Paste below skin, very soft and smooth. After extraction, the oil was clear and of light color.

Analysis of oil:

Specific gravity	.9356
Ash	.195% (light)
Iodine No.	163.
Acid value	10.5

TEST NO. 12.

Graphite.

Condition on Opening.—Very soft and smooth paste. After extraction, the oil was clear and light in color.

Analysis of oil:

Specific gravity	......
Ash	.201% (light)
Iodine No.	158.5
Acid value	13.3

These results show that inert pigments such as barytes, iron oxide, graphite and carbon black do not enter into chemical action with linseed oil; the percentage of ash found in the oil extracted from the above pigments being practically identical with the percentage shown by the raw oil. That such pigments may, however, have some physical action upon the oil, that will later develop a chemical change therein, seems evident. The thickened condition of the oil extracted from the silica paint, and the low iodine values and high acid values shown by all of the oils extracted from the above-mentioned inert pigments, would give credence to the above statement.

The pigment that is ordinarily termed American vermilion, the true form of which is a basic chromate of lead, seems to have had no very marked effect upon the oil in which it was ground. It would seem, therefore, that it would prove quite practical to transport this pigment in paste form. On account of its value as a protective of metal, it will probably replace, to some extent, the use of red lead for priming steel. The pigment red lead had a marked hydrolyzing reaction on the oil in which it was ground. The latter contained a very large percentage of lead linoleate, free fatty acid, and glycerin. The iodine number of this oil was lower than that of any other extracted. It is, of course, well known that red lead, on account of its tendency to harden in the package, is seldom put up in mixed form. The dry pigment is generally mixed with oil just before application, from 30 to 35 pounds of pigment to a gallon of oil being the proper consistency for painting.

Zinc oxide and zinc lead had but slight action with the oil, while basic carbonate-white lead showed somewhat greater action, but not sufficient to be of any detriment. With paints containing mixtures of lead and zinc pigments only slight action was shown. The perfect condition of these paints indicates that any properly-prepared combination pigment paint may be safely stored in cans for long periods without bad effects, provided the oil used is of normal grade.

The most astounding change shown in the tests was that in the iodine values of the oils extracted from all of the paints. It would appear, therefore, that when paints are stored for a considerable period of time and then examined for the iodine value of their oil content a lowering of the iodine value should not constitute cause for rejection or be sufficient evidence to state that the oil was adulterated with oils of lower iodine value. Cognizance of this statement should be given by railroads and purchasing corporations which have adopted specifications for oil paints.

As is well known, linseed oil is a mixture of tri-glycerides of fatty acids. In other words, fatty acids are combined with glycerin in the proportion of three equivalents of acid to one equivalent of glycerin, the latter material acting as a tri-atomic alcohol or base. The fatty acids in linseed oil, among which may be mentioned oleic acid, are of an unsaturated nature, being capable of taking up large quantities of oxygen. The combination of these fatty acids with glycerin may be effected by certain enzymes which exist in the seed of the plant. Moreover, the resolution of such compounds with a consequent breaking away of the acids, from the glycerin, to a free condition, may be accomplished by enzymes which have hydrolyzing properties. This splitting-up reaction may also be effected by several methods of a chemical nature. The hydrolyzing effect of moisture is sometimes of considerable moment and is probably responsible to some degree for the small percentage of free fatty acid which is generally present in all linseed oils. That some oils have higher acid values than others is well known, the acid refined oils being especially high in free acid; treatment with various mineral acids accelerating hydrolysis. The most rapid form of hydrolysis is effected with strong bases such as soda, the ultimate products being water-soluble soda soaps and glycerin. When the hydrolyzing base is a relatively insoluble product and of a metallic nature such as litharge, the hydrolysis of the oil is slow and only partial, there being formed a water-insoluble lead soap, glycerin, and some free fatty acid.

When hydrolysis has taken place in a paint, considerable thickening is observed. In the tests which are charted above it will be observed that the most extravagant example of hydrolysis was shown by the red lead paint. The oil from this paint showed over 15 per cent. of inorganic lead compounds in the ash. It will also be noticed that the oil had become very acid in nature and had the appearance of a thick jelly, which may be accounted for by the large percentage of glycerin present. Although the red lead paint was very thick, difficult to break up, and too heavy for brushing, it was not really hard. The writer has had occasion, however, to examine several samples of paint recently which were very much harder than the red lead, one, in fact, being so hard that a knife was required to make any impression upon its solidified surface. These paints, moreover, contained pigments of a basic nature, containing a very high percentage of lead and zinc. An examination of the oil in which these paints were ground showed acid values ranging from 8 to 16. That the reaction of the free acid upon the pigments was the real cause of the hardening of the paint was the writer's conclusion. A series of tests were therefore made, in which was included the treatment of paints with small percentages of free oleic acid, one of the most prominent constituents found in oils of a high acid value. There were also included tests in which paints were treated with sulphites, there existing in the paint industry a false belief that lead and zinc pigments are apt to body and harden in oil if they contain even traces of sulphur dioxide or sulphites. Those who have held such a belief should some time examine paints made of sublimed blue lead, a pigment which contains nearly 5 per cent. of metallic sulphites and sulphides. This pigment will remain as a smooth paste in oils for months without any apparent hardening.

Small quantities of dry zinc and lead pigments (basic carbonate-white lead, basic sulphate-white lead, zinc oxide, and zinc lead) were ground in a pure raw linseed oil having a normal acid value of approximately 2.8. After standing for three days, no tendency toward hardening was shown by any of the paints. They were then divided into small portions, and to each type were added various materials which were under suspicion as having, when used, some contributing effect in the hardening of paint. The following table shows the results of these experiments:

Treatment with 20 per cent. gloss oil (½ rosin, ½ benzine)............	Considerable hardening shown in 24 hours, indicating action between the acid rosin (resinic acids) and the basic pigments.
Treatment with 2 per cent. sodium hyposulphite	No effect noticed in 6 days.
Treatment with 5 per cent. oleic acid.	Hardening occurred in two hours and increased with age. Paint resembled hard putty.

From these results it is apparent that oils of an acid nature are the most active cause of paint hardening. The use in cheaper paints of substitutes for linseed oil, which contain large percentages of rosin, as well as the promiscuous use of acid rosin driers, has been the cause of the hardening of many paints. Linseed oil containing high percentages of acid is, of course, dangerous. It is evident, therefore, that a careful consideration of the vehicle portion of a paint is even more important than the pigment part, and a careful record of the acidity of paint oils should be kept by the grinder.

The author wishes to acknowledge the assistance of Messrs. L. G. Carmick and J. E. Heckel in the analytical determinations.

Nitrates from the Atmosphere in Germany. ANON. (*Oil, Paint and Drug Reporter,* June 24, 1912.)—Nitrate manufactured from the air by the Norwegian and Swedish plants is slowly finding its way to the German market. It is expected that very shortly Norwegian saltpetre will be shipped in large quantities to the centres of consumption. At present the artificial nitrate is selling at 8 to 9 pfennigs more per kilo. than Chile saltpetre, but it is expected the prices will soon be equalized. In 1911 only 493.3 metric tons of sodium nitrate were imported from Norway, as against 730,939 tons received from Chile. Also 473.4 tons of ammonium nitrate were imported from Norway and 139.2 tons from Sweden, and 14,494 tons of calcium nitrate from Norway and 1,033.6 tons from Sweden. New plants for extracting nitrogen from the air are in course of construction not only in Sweden and Norway, but also in Upper Bavaria, in the Tyrol, in Switzerland, and in the valley of the Rhine.

"Electrit" Grinding Wheels. ANON. (*Amer. Mach.*, xxxvii, 1, 24.)—"Electrit" is an abrasive made from pure aluminum oxide by melting it in an electric furnace at a temperature of about 3000° C. (5400° F.). Its specific gravity is less than that of emery and corundum, but its hardness is considerably higher, about 9¼ on the 10 degree hardness scale. The grain of "electrit" is almost amorphous, resistant under pressure and shock, tough and not brittle. "Electrit" grinding wheels are bound ceramically, are proof against moisture and acids, and can be used either for wet or dry grinding.

On the Use of Oxygen Under Pressure to Determine the Total Carbon of Ferro-alloys. P. MAHLER and GOUTAL. (*Mon. Sci.*, ii, 848, 546.)—To obtain complete and perfect combustion the addition of an auxiliary combustible is necessary. Good combustion is attained by adding to the sample two to three times its weight of metallic iron, and lead oxide or copper oxide in amount equal to one-half of the total charge.

"Overshooting" of Lamps in Candle-power. E. J. EDWARDS. (*Elec. World*, lix, 1124.)—There can, theoretically, be no overshooting of temperature when the voltage across the lamp is maintained constant, if the resistance changes are coincident with the changes in temperature. Most cases of overshooting are due to an illusion; for a constant light source seems to flash above its subsequent value, when quickly uncovered before a "dark" adapted eye. From these experiments there is no evidence, in tungsten lamps, that the luminous intensity overshoots its normal value.

Decomposition of Water by Magnesium at Ordinary Temperature. A. W. KNAPP. (*Chem. News*, cv, 253.)—When magnesium is mixed with water no reaction is observed at ordinary temperatures, although the formation of magnesium hydroxide and the liberation of hydrogen is an exothermic reaction. This is explained by saying that the film of hydroxide first formed covers the metal and retards further action. However, if magnesium powder be added to ten times its weight of water, and then palladious chloride equal to one-hundredth part of the weight of the magnesium, a brisk evolution of hydrogen occurs. The magnesium reduces the palladious chloride, forming metallic palladium, which acts catalytically. The small amount of magnesium chloride formed possibly accelerates the reaction by dissolving the hydroxide. The temperature rapidly rises until the water boils and white hydroxide is formed. The palladium, which has accelerated the decomposition of the water, now accelerates its formation, for it is warm, and some of it rising on the bubble-films, which separate the hydrogen from the air, causes the hydrogen to ignite spontaneously.

METROLOGY IN RELATION TO INDUSTRIAL PROGRESS.[1]

BY

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BEFORE the development of modern science, metrology included only the simple weights and measures necessary in commerce and trade. The adoption and preservation of standards of weight and measure, the means of making them accessible to the public, and the enactment and administration of laws preventing the use of incorrect weights and measures have been questions of vital interest to every nation from the beginning of history.

Naturally, the early standards had their origin in some object in Nature, thus recognizing the most vital principle of modern metrology, namely, reproductibility. A history of these standards would prove most interesting. Each community had its own standards, but as trade grew, due largely to the improvement in transportation facilities, it became necessary to unify the standards of communities doing business with each other. During the past century every commercial nation has been compelled to put its standards on a national basis. Even in our own country, as late as 1830, the Secretary of the Treasury was compelled to unify the weights and measures in use in the various customs houses, and as copies of the standards he adopted were furnished the States by direction of Congress, and in turn adopted by them, this act constituted what may be termed the unification of our national standards. Similarly, the time is not far distant when the same force which compelled the various sections of each country to adopt uniform national standards will bring about international uniformity. The countries of the world are closer together to-day, commercially, than were the sections of each country a hundred years ago.

The developments of modern science necessitated the introduction of a new factor in metrology, namely, precision, since precise measurements form the foundation of practically all scientific investigation. Commercial standards were not sufficiently reliable or accurate for scientific purposes. The progress of science demanded correctly-defined units and accurate material standards for each physical quantity to be measured, whether in the field of mechanics, heat, light, or electricity. Practically all of these units and standards are based upon the fundamental units of length, mass, and time, and involve measurements of these three fundamental quantities of the utmost refinement in order that the derived units may be determined with the order of accuracy required even in the industries. Hence, much scientific effort has been expended upon the improvement of the units and standards of these fundamental quantities, and the derived units and standards form a never-ending field of scientific research.

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[1] Presented at the stated meeting of the Institute, held Wednesday, May 15, 1912, when Dr. Stratton received the Institute's Elliott Cresson Medal.

But the field of metrology does not end with the fixing of the fundamental standards of length, mass, and time, and the derived units in the field of mechanics, such as force and energy and power, or the deriving and fixing of the various standards used in measurements of heat, light, and electricity, but it includes the determination of a large number of values known as physical constants, such as the mechanical equivalent of heat, the boiling points of liquids, the melting points of solids, thermal and electrical conductivities, the optical and radiation constants, and many others. Accurate values of these constants are as necessary as correctly-defined units or accurate standards of measurement. They enter into practically all scientific work, whether pure or applied, and may be termed " standard values."

Again, the field of metrology is rapidly being extended to include standards of quality. It is often desirable, especially in the industries, to define the quality of a material in terms of its physical and chemical properties, to specify, as it were, its standard of quality. As metrology forms the basis of investigation in the field of natural science, so do the natural sciences constitute the principal factor in industrial progress. When Germany determined to take a leading part in the industrial world, she began by encouraging scientific investigation and instruction. She had reached the front rank in the scientific world long before reaching that same position in the industrial field, and her phenomenal industrial progress can be attributed to the application of scientific methods and principles more than to all other factors combined.

Metrology has a direct bearing of great importance upon industrial progress, as shown in the interchangeable method of manufacturing, a method depending upon the accurate measurement of length, the accurate measurement of temperature in the steel, glass, ceramic, and other industries where it was formerly estimated, and no field of industry owes more to metrology than that of applied electricity. These are but a few of the vast number of cases that might be recited, but metrology is probably far more important to industrial progress, indirectly through the channels of applied science.

This country has enjoyed a remarkable period of industrial prosperity, due to the enormous home consumption of our manufactured products by a rapidly-increasing population of a new and growing country, and the retention of the home market for our own use. Nevertheless, competition as to quality is growing very keen, and our manufacturers are becoming aware of the great importance of scientific investigation, the leading industries are rapidly establishing research laboratories in which units and standards of measurements are the principal means of attacking the difficult problems they are called upon to solve. These laboratories are quite as exacting in their requirements as to accuracy as the laboratories of scientific institutions. The usefulness and efficiency of such laboratories are increased manyfold by the access to accurate, reliable standards and methods of measurement. There is scarcely a business transaction, an exchange of commodities, an article manufactured, or a structure erected that does not refer in some way, either directly or indirectly, to standards of measurement.

Every progressive country has recognized early in its history that the fixing of standards is a governmental function and has early made provision for the maintenance and use of the standards used in trade. Later, these countries, recognizing the new and broader field of metrology and its vital relation to industrial development, have established national institutions equipped for scientific investigations in all branches of metrology. The first of these was the Physikalisch-Technische Reichsanstalt, established by Germany in 1884, dealing with the newer branches of metrology, including light, heat, electricity, and the determination of important physical constants in these same fields of science. This institution was, in addition to the laboratory of the Normal Eichungs-Kommission, having to do only with the ordinary standards of trade, and its phenomenal influence upon the industrial development of Germany is too well known to comment upon at length at this time. Later there was established in Germany still another institution, the Material Prüfungsamt, dealing with the subject of metrology in its newest and broadest sense, namely, the determination of the properties of the more important materials of construction and other industrial products. While this latest standardizing institution is essentially supported by the Prussian Government, its influence is felt throughout the Empire.

In 1898, Great Britain established the National Physical Laboratory near London, again an institution made necessary by the ever-widening field of metrology. This institution is growing by leaps and bounds and is already an important factor in the industrial development of that country. It has taken a place in the front rank of scientific laboratories and is doing a great work. In our own country the founders of the Government gave to Congress the responsibility of fixing the standard of weights and measures by constitutional provision. In framing this paragraph of the Constitution, they no doubt had in mind as examples the standards then recognized as necessary; but the principle involved and established applies equally well to the standards of electricity, heat, and all others that have become necessary, or may become necessary in the future, to commerce, trade, and industry.

As in other countries, the weights and measures of trade were first provided for, but, curiously, never by direct legislation, except in the case of the Troy pound of the Mint. The Superintendent of the Coast Survey, the first scientific bureau of the Government, purchased a standard of length from a London instrument-maker, since such a standard was the first thing necessary in making the coast and geodetic surveys of the country. The Secretary of the Treasury secured a copy of the British Troy pound for use in the coinage of money and from which the avoirdupois pound was derived, the grain of each being the same. He further adopted the Winchester bushel and the wine gallon, which had been in use in the Colonies. In 1836, the British standard of length was destroyed by fire. In reconstructing a new standard from the best copies of the old one, several copies were made, one of which was presented to this country in 1856.

The metric system of weights was legalized by Congress in 1866. In 1872, a conference was held in Paris by the representatives of thirty countries, the United States being represented, and provision was made for the construction of new metric standards of length and mass. They were made of an alloy of platinum and iridium, the most durable materials known, and by the most accurate methods known to science at the time. The copies sent to this country in 1890 were adopted by the Secretary of the Treasury as our metric standards. In 1893, the relations between the yard and the meter and the avoirdupois pound and kilogram were fixed by that official, based, of course, upon an accurate comparison between the standards of the two systems. From this time the meter and the kilogram became the fundamental standards for both systems, thus giving to the common system the advantages of the metric, so far as permanency and accuracy are concerned. One should not confuse the terms "unit" and "standard"; if the relation between the yard and meter—both units—is known, then it is only necessary to measure off on a subdivided meter that portion which has been defined as equivalent to the yard. In a similar manner, the pound is determined from the standard kilogram.

Briefly, this is the history of our fundamental standards, both for industrial and scientific purposes. A small office of weights and measures, with four or five employees, had grown up in the Coast Survey, a bureau of the Treasury Department, in which the standards of the public were compared, to a limited extent, with those of the Government, the functions of the office being exercised mainly for Government uses. This office was superseded in 1901 by the Bureau of Standards, a new bureau in the Treasury Department, with functions sufficiently broad to cover the great variety of standards now required by the industries, the value of physical constants, and such properties of materials as are needed in standardizing them. This bureau was transferred to the Department of Commerce and Labor at the creation of that department. It might equally well have been termed the National Bureau of Metrology. Its employees, scarcely more than a dozen at the start, now number approximately 300; it is provided with three large, well-equipped laboratories, with another in process of construction. Fortunately, the various metrological functions were here combined in one institution instead of several, as in those countries where they have been taken up one after another, thus ensuring a co-operation between the various branches of metrology and which cannot be economically or efficiently separated one from another.

It is not my purpose to describe in detail the work of the Bureau of Standards, but a few examples of the work now in progress will perhaps illustrate better than by any other method the relation of metrology to the industries. Those familiar with manufacturing need scarcely be told the importance of length, mass, volume, and density measurements in all branches of industry. The requests for the comparison of length standards come from the makers of all kinds of length-measuring instruments, from the makers of machinery and tools. Practically all of the measuring tools of every sort used by workmen in construction are made from standards that have been compared with those of the bureau. The bureau is never without the standards of the makers of weights; the standard weights of manufacturing concerns, railroad companies, or the precision weights used in industrial laboratories, all awaiting comparison with the Government standards. Oil companies have their standards of capacity verified. Gas meters are referred to standards of capacity—as well as the glass measuring apparatus used in industrial and scientific laboratories. Hydrometers, or instruments for measuring the densities of liquids, are used in great quantities and variety; tables of densities of various kinds must be prepared for use in connection with them. The internal revenue on alcoholic liquors, amounting to many millions of dollars annually, is collected in accordance with the readings of these instruments, all of which are tested at the bureau. These are but a few of the instances involving standards of length, mass, capacity, and density, to which one of the largest sections of the bureau is devoted.

The electrical industries are as exacting as to their requirements of standards as scientific laboratories. This industry has, perhaps, more than any other, adopted scientific methods and precision measurements. The standards of the makers of electrical measuring instruments, as well as those of the producers and users of electrical energy, must be compared with a common standard, and that standard (or standards, as there are several of them) must be derived from the fundamental standards of length, mass, and time—an exceedingly difficult operation. The Electrical Division of the bureau was called upon recently by the electrical industries for a determination of the conductivity of copper—a physical constant of great importance to that industry—and it is frequently called upon to determine the electrical properties of materials. It is undertaking an investigation of the electrolysis effects of stray currents upon underground pipes or other metal construction with a view of determining some of the data necessary in standardizing electrical construction and the prevention of electrolysis, an excellent illustration of the many investigations in progress at the bureau for the determination of the properties of materials under specific conditions, in order that they may be more properly used.

In addition to the vast number of temperature measurements made at ordinary ranges in industrial processes, many of these processes depend for their success upon measurements of high temperature. This is especially true of the steel, glass, porcelain, and similar industries. No branch of metrology presents more varied problems or is more closely connected with industrial progress. The calorific values of gases and other substances are being determined. Only a few days ago the refrigerating industries requested the bureau to determine the heat constants of ammonia and brine, the heat-insulating properties of materials, and other constants needed by that important industry.

Many of the constants and values given in tables of reference are out of date and need to be redetermined with all the precision possible in modern metrology.

One scarcely thinks of optical measurements in connection with metrology or industrial progress, and yet optical measurements are an important factor in both. The applications of spectrum analysis are many. The duty upon imported sugars, amounting to seventy or eighty millions of dollars a year, is collected according to the amount of pure sugar they contain, as determined by measurements involving the principles of polarized light, and every one is familiar with the relation of photometry to the gas and electric industries. Standards of color and color-measuring instruments are desired that are applicable for the measurement of the color of textiles, paper, pottery, and butter, and many other materials. In fact, an instrument for measuring color has been recently developed at the bureau, and the substances mentioned are those that were being measured but a few days ago during my visit to this particular laboratory. Investigations are in progress for the purpose of determining the data necessary in defining the optical properties of the various lens combinations, such as field glasses, photographic lenses, telescopic objectives and others, and also the means of specifying and measuring these properties.

Metrology, in the broad sense, includes not only the various fields of physics, but chemistry as well. Scarcely a problem is taken up, either in connection with standards of measurement, constants, or the properties of materials, that does not involve chemical analysis. Standard irons, steels, ores, and so forth, of known compositions are required by the metallurgical industries; the chemical industries are demanding standards of purity in reagents.

Standards of quality have to do with the manufactured product rather than the process of manufacture, and they have an exceedingly important bearing upon industrial products. The newest and largest section of the Bureau of Standards is that devoted to the investigation and determination of the properties of the more important structural and engineering materials in order that they may be correctly specified and most efficiently used. The bureau tests large quantities of such materials purchased by the Government. In doing this, it is brought in contact with faulty definitions, imperfect specifications, and, in many cases, the entire absence of standards of quality or suitable methods of testing. This work is of great financial value to the Government, but it is insignificant as compared with that of the knowledge that is gained by doing it and which can be given to the public.

The bureau endeavors to serve as a clearing-house for knowledge pertaining to metrology. Scarcely a day passes that it is not visited by several representatives of various industries seeking information as to standards, methods of measurement, or the properties of materials; every mail brings scores of such inquiries from every section of the country and from all branches of industry. The bureau serves as referee in many cases of dispute when questions of standards are involved, and it is frequently instrumental in bringing about an agreement between manufacturers and users as to standard specifications.

There is a decided and rapidly-growing tendency on the part of the public to purchase structural and other materials according to properly-framed specifications, and to ascertain, by suitable tests, whether or not the articles purchased comply with the specifications. Hence, the bureau encourages the establishment of local testing laboratories, especially in the large cities, by furnishing them with standards, assisting them in the preparation of specifications, and giving them the results of much valuable experience gained in doing similar work for the Government. The time is not far distant when every large city will have its testing plant, dealing not only with the measurements involved in the public utilities, but testing all materials purchased for use in public work.

Finally, I would call attention to the efforts of the bureau toward promoting international agreement as to the fundamental questions involved in metrology. Largely through its influence a very close co-operation has sprung up between the various national bureaus. They are continually exchanging standards and comparing methods. The necessity for international agreement in such matters is becoming daily more and more apparent. The scientific world employs only international standards—why should not the industrial and commercial world enjoy the same privilege?

In conclusion, I would state that if there is one thing above all others for which the activities of our Government during the past two or three decades will be marked, it is its original work along scientific lines, and I venture to state that this work is just in its infancy. The expenditures of the Agricultural Department, great as they have been, have produced results of untold value to the agricultural interests of the country, and it is hoped that the Government may take a similar position in reference to other branches of our industrial interests.

Utilization of Asphaltum Residues. ANON. (*Oil, Paint and Drug Reporter,* June 24, 1912.)—It is shown by the Geological Survey's publication, "Mineral Resources," that the chief feature of the asphaltum industry in 1911 is the great extension of the use of residues from the asphaltic varieties of petroleum as binders on the surfaces of macadam roads in order to prevent deterioration. The asphaltum used for this purpose increased from 159,424 tons in 1910 to 234,951 tons in 1911. The importation of soft asphaltum from Venezuela, which is admirably suited for this purpose, is increasing. A by-product of the oil industry is fast supplying the demands for asphaltum in the United States. The petroleum from California and Texas has furnished large supplies of asphaltic residue, which, when treated with air, becomes sticky and even elastic to a certain extent. Elastic material for roofing and substitutes for rubber in automobile tires have been obtained from asphaltic residues by the blowing process or by treating with sulphur. This sulphurization of asphaltum has been applied with good effect to elaterite and similar hard asphaltums from eastern Utah.

The Mass of the Particles Which Emit the Two Spectra of Hydrogen. C. FABRY and H. BUISSON. (*Mon. Sci.,* ii, 848, 551.)—Hydrogen gives two very different spectra: the first composed of rays whose distribution obeys Balmer's law; the second, in which the rays are very numerous and are distributed irregularly. An attempt was made to ascertain if the one or the other of these spectra was not emitted by a complex atomic aggregation, such as the molecule. The study of the size of the rays enables us to determine the mass of the particles which emit the different radiations, referred to the ordinary system of atomic masses. Now the formulas referred to enable one to deduce from the number of the limiting order of the interferences given by the rays of the second spectrum the mass of the particles which emit these rays; this mass is found to be very appreciably equal to the atomic mass of hydrogen. The rays of the second spectrum then are emitted by corpuscles identical with the atom, or which differ but very little from the atom, and not from a combination of several atoms. It is concluded, therefore, that the rays of hydrogen, those of the secondary spectrum as well as those of the spectrum in series, are produced by particles of the same mass as the hydrogen atom.

Preparation and Heat of Formation of Magnesium Nitride. C. MATIGNON. (*Mon. Sci.,* ii, 848, 546.)—The best method of producing magnesium nitride is to pass a current of absolutely dry ammonia gas over finely divided magnesium heated in a nickel or magnesium boat. The heat of formation of the nitride from its elements is 119.7 calories, according to the equation $3Mg + N_2 = Mg_3N_2(\text{solid}) + 119.7$ calories. Hence nitrogen has a high affinity for magnesium.

WATERWAY IMPROVEMENTS.[1]

BY

LEWIS M. HAUPT, C.E.

By virtue of the increased tonnage and draught of vessels, the constant deterioration of river channels and harbor bars has led to the expenditure of enormous sums of money in efforts to maintain the world's maritime traffic through such channels.

Attempts have been made to solve this complex problem of deterioration by the use of jetties in pairs, aided by dredging, and great progress has been made in the efficiency of hydraulic dredges. Mechanical appliances do not modify, however, the forces which mould the beds of the channels in plastic material and can never serve to automatically maintain the depths they tentatively secure.

For the purpose of ensuring greater safety, speed, and economy in the maritime interchange of trade, the expenditures by all nations will aggregate more than $100,000,000 annually. Yet the possibility of preventing such expenditures by utilizing the energy of the maritime forces themselves, instead of endeavoring to combat those forces, does not seem to have been realized until within the last few years, when the utility of such a system has been fully demonstrated, even under exceptionally adverse conditions.

Prior to the improvement of the South Pass in 1879 by two curved jetties, the ruling depths of the Gulf of Mexico at the inlets were from 3 to 12 feet, and large sums of money had been expended in efforts to obtain deeper water, but with little effect. At Galveston, however, after a lapse of some thirty years and an expenditure of over $10,000,000, a tortuous channel of more than 30 feet has been provided, though the bar has advanced over three miles and constant dredging is required to maintain the depths.

At Liverpool, England, it was estimated that the removal of 9,000,000 cubic yards of material would suffice to secure a 30-foot channel to the port.

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[1] Abstract of paper presented at the meeting of the Mechanical and Engineering Section held Thursday, February 8, 1912.

Since 1890, however, more than 121,000,000 tons have been dredged and the depth resulting from it was, in 1908, 28 feet.

In sedimentary streams, jetties merely serve to temporarily extend the flanks across the bars and to deposit the silt beyond, in the path of navigation. Thus, the delta of the Mississippi deposits 440,000,000 cubic yards annually, of which more than 102,000,000 cubic yards traverse the Southwest Pass, which is being improved by jetties and dredging. The bar is now over half a mile beyond the ends of the jetties.

Problems such as the above require for their solution a consideration of all the forces and their results, as recorded by the physical forms which they create.

Before the Civil War it was the policy of the Government to aid the States and localities in the conduct of public works on river and harbor improvements. The total expenditures made for that purpose from the National Treasury were less than $15,000,000. Since the Government assumed control of the rivers and harbors, however, it has expended to date about $600,000,000 in efforts to meet the demand for deeper channels. The average yearly appropriations made for this purpose during the last decade are less than $25,000,000, and the commercial interests are demanding double this amount to meet the requirements of trade. The Administration is committed to the policy of completing the existing approved projects, aggregating more than $300,000,000, before any new obligations are assumed.

In making analyses of the several methods of improvements adopted, due consideration must be given to the local physical conditions of tides, currents, winds, waves, and fluvial waters at the mouths of sediment-bearing streams. The littoral drifts, character of material, and rates of movements of purely tidal inlets must also be considered.

The official reports of the Government Engineers, the United States Coast Survey, and other publications furnish data on the methods adopted in the following cases of some of the principal harbor and river entrances along the alluvial seaboard of the United States:

THE DELAWARE RIVER.

For a generation efforts have been made to deepen this river, first to 26, then to 30, and now to 35 feet.

The present project for a 35-foot channel contemplates the use of dikes. The estimated cost of the project is $10,920,000, with $300,000 for its maintenance. The time required to complete it is six years.

Since 1836 there has been expended a total of $10,876,002.18, and the depth as reported is about 28 feet at mean low water. The 26-foot channel project was inaugurated in 1885, and in 1899 was merged before its completion into the 30-foot project, which is now embodied in the present 35-foot plan.

Since 1870 there have been many changes of officers in charge of these improvements and of Boards of Engineers reporting on modifications. The plans have been changed from the prohibition of depositing dredged material in the bed of the stream to the construction of dikes, with a return to dumping behind islands or in artificial enclosures, and again to partial dams connecting natural islands with the adjacent shore. The effect has been to throttle the tides and in some instances, where the water is excessively deep, to make it still deeper, with a consequent shallowing of the resultant shoals. The dikes have been restrained because of encroachment on the riparian rights of the adjacent States, and are now located so as not to act as training walls to maintain the channels from which they are too remote or placed nearly at right angles, greatly reducing the normal cross-section.

THE CHARLESTON ENTRANCE.

In 1878 it was proposed to secure a 21-foot channel over the outer bar of this entrance by two low-tide and submerged jetties at a cost of $3,000,000.

This was modified ten years later, when it was projected to raise the jetties and extend their length at a cost of $4,380,500.

In 1899 another modification was made to procure a 26-foot channel by building larger dredges. In 1910 again, with still more powerful dredges, a 28-foot channel was aimed at, this to cost $371,616.88 additional, with $40,000 for maintenance.

The total cost to June 30, 1911, was $4,783,265, and a good 26-foot channel was reported. Tide, 5.2 feet. The improvement has, however, had no effect on freight rates, although the insurance has been slightly reduced. A project for further enlargement is pending. The three dredges, when working, during the year removed 1,212,722 cubic yards, bin measure, but the solid removed was apparently much less and the cut is filling from the north side. The average cost per yard was 10.89 cents.

THE ST. JOHN'S BAR.

To obtain a navigable channel of 15 feet from Jacksonville, Fla., to the sea, a distance of 27.5 miles, it was estimated, in 1879, that two convergent low-tide jetties, supplemented by dredging, would be required and that the cost would exceed $1,000,000. The project, when carried out, resulted in a 13-foot channel at a cost of $1,417,000.

Modifications were made in 1896 and again in 1903 to secure a 24-foot channel, by raising the jetties and by dredging, at a cost of $2,176,750. The work was nearly completed and $3,017,890 had been expended, when a new project was adopted in 1910 for a 30-foot channel, at an estimated cost of $2,852,000.

About 4 per cent. of this latter modification is completed, and the maximum available draft is 22½ feet.

CUMBERLAND SOUND, GEORGIA.

The bar in this sound carried originally from 11 to 12.5 feet of water at low tide and was very unstable, drifting through a range of 1½ miles. A proposal was consequently made in 1879 to improve it by two low jetties, 3,900 feet apart, which were expected to give a 19-foot channel by dredging at a cost of $2,071,023. There was expended under this project $932,500.

In 1891 a Board of Engineers recommended the raising of the south jetty to high water throughout, in case the low jetties failed to secure sufficient depths. The plan was modified by Captain Carter in 1895 for two rip-rap jetties extending to 30 feet of water and estimated to cost $2,350,000. Captain Carter's plan was approved.

The reported depth in 1897 was but 13 feet, and the channel crossed the south jetty about 7,000 feet from its initial end.

To enable vessels to enter the port of Fernandina, a portion of the south jetty was removed and an emergency appropriation of $500,000 was passed by Congress to relieve the port from closure.

On the building up of the outer end of the north jetty a channel was soon scoured out under its lee by the natural action of the currents, and this has since been deepened by dredging, so that the controlling depths last year were 24.5 feet.

In this connection it should be recorded that on October 8, 1890, or about a year after the receipt by him of the "Physical Phenomena of Harbor Entrances," Captain Carter recommended a change of plan in the location of the jetties and the abandonment of the south jetty, with the substitution of a concave outer jetty on the north side of the channel. He estimated that his plan would save $1,096,417. Report of 1901, page 1600, gives the opinion of the Board of Engineers on this plan, however, which is as follows:

"It does not think that a single jetty on the north side of the channel curving gently to the south would secure the deep water needed, but that two jetties are necessary. . . . The idea that a curved channel conforms to the natural requirements of the site and opposes the action of the natural forces less than any other is believed to be fallacious."

THE MOUTH OF THE MISSISSIPPI.

In 1803 Louisiana was purchased by the United States, to secure control of the outlet to the Gulf, and fifty years later the Government began to rake and dredge the bars in efforts to obtain a channel of 18 feet instead of from 9 to 12. Three hundred and thirty thousand dollars was appropriated in 1856 for the purpose of building jetties at the Southwest Pass and stirring up the bottom, but the channel was only maintained so long as the stirring was continued, which was only for one year. By 1870 a powerful dredge was built and used to stir up the bottom, throwing the material into the current, but it did not succeed in maintaining a channel, so that in 1871 the proposition was made to dig a canal at Fort St. Philip, to cost $10,273,000, and secure a passage 25 feet deep by locks. This was met by a proposal by James B. Eads to construct two jetties and obtain 28 feet by dredging at a cost of $10,000,000. Captain Eads's plan was submitted in 1874. In 1875 a Board of United States Engineers reported a project for two straight jetties, to be supplemented by stirring or dredging, to secure a 25-foot channel, and to cost, if at the South Pass, $7,942,110, and if at the Southwest Pass, $16,053,124. The Chief of Engineers declined to approve this project, and Captain Eads then proposed to open a 30-foot channel at Southwest Pass for $8,000,000 and to maintain it for 20 years at a cost of $150,000. Congress gave him the South Pass work in March, 1875, and in July, 1879, he had secured a channel 200 feet wide at the 26-foot depth, with a maximum of 30 feet, under his contract for $5,250,000.

Thus, 76 years after the purchase, the river was opened for deep-draught vessels by a channel supposed to be adequate for all time. It was not long, however, before the commerce demanded a greater channel, and in January, 1899, a new Board estimated on two parallel straight jetties to open the Southwest Pass at a cost of $13,000,000 for construction and $390,000 annually for maintenance.

At the request of a member of the River and Harbor Committee, the writer prepared a project for a 35-foot channel and offered to open the pass at a cost of $6,000,000, with $100,000 for maintenance. The plan was referred to a Board of Engineers, which modified it, suggesting what was known as the "bottle-shaped" jetties, to be accompanied by dredging, at the low cost of 4 cents per yard; total cost, $6,000,000. As these two jetties, at distances varying from 3,000 to 7,000 feet apart, constituted a trap for sediment, the project was again modified, though not improved, and a contract made for its construction in 1903, after the writer had demonstrated the probable results of the modifications.

The following extracts from the last report of the Chief of Engineers will indicate the present conditions of the work and results:

Southwest Pass was obstructed by a bar having 9 feet depth, and in the pass proper they reached to from 26 to 83 feet, mean low water. The existing project was adopted by the act of June 13, 1902, for a 35-foot depth and 1,000 feet in width, by dredging, two jetties to maintain the channel, the closure of all minor channels and removal of obstructions, sills, etc. The act also authorized the Secretary of War to modify the plans of 1900. Construction of jetties began December 31, 1903, and they were completed January 5, 1908, at a cost of $2,627,087.60. Total lengths about 37,000 feet. Cost, about $71.54 per foot. The dredge "Barnard," built at a cost of $240,000, reached

New Orleans September 3, 1904, and began work in the pass, April 21, 1905. Since that date dredging has been continued with the "Barnard," "Benyaurd," "St. Johns," "Sumter," and "Atlantic," and 8,131,256 cubic yards were removed up to June 30, 1911. Dredging was also done under contract in 1907 and 1908, when 3,574,318 yards were taken out and $466,035.31 paid the contractor. Sills were placed, outlets closed, buildings erected, machinery bought, and an additional dredge ordered, all of which have caused an expenditure of $5,620,276.88. Operations during the last fiscal year have resulted in the removal of 3,163,214 cubic yards by dredging.

On April 13, 1911, a contract was made for extending the east jetty 3,000 feet and the west jetty 3,750 feet and the building of two spur dikes. Ten spur dikes were built in connection with the jetties aggregating 7,240 feet in length. The available depth of channel is 31 feet at mean low water. The available depth in the South Pass at the same date was 29 feet.

"Any improvements in a stream like the Mississippi must be effected, both in time of execution and cost of operation, by conditions beyond human control."

Deductions.—The total prism of excavation since April, 1905, is 14,858,788 cubic yards, giving an average yearly removal of 2,409,528 cubic yards at an average cost of 6.33 cents per yard, instead of 4, as estimated, or nearly 60 per cent. higher. The estimated discharge of silt through this pass is 102,000,000 cubic yards, so that the dredges have handled only about 2 per cent. of the total, and, the outlets being closed, the residue must be discharged through the jetties, hence the rapid advance of over 3,000 feet in 7½ years since this project was begun. The normal rate was a half mile each decade. The ruling dimensions of the channel on June 30 were, depth 31 and width 360 feet. The spurs built during the year have aided in the deepening and indicate that the jetties are too far apart, and the groins are filling with sediment, as they should. It is manifest, therefore, that the jetties have hastened the advance of the bar and increased the deposits beyond them, while the channel is not self-maintaining. The east jetty has settled 1.6 feet and the west jetty 1.8 feet since being capped. The total appropriation has been $6,925,643.89, of which $5,620,276.72 is expended.

TAMPICO HARBOR AT MOUTH OF PANUCO RIVER, MEXICO.

(*Extract from "Shipping Illustrated" for February 18, 1911.*)

"The Mexican Government has made an appropriation of $10,000,000 to extend the jetties at the mouth of the Panuco River at Tampico, by which the present deep-water harbor is formed, farther into the sea for a distance of 700 feet and for dredging the bar at the mouth of the river. The stone breakwaters will be concreted on the sides and top and a walk constructed thereon."

The bar at the mouth of the Panuco River was about 4,400 feet off shore, and its depths varied from 5 to 12 feet with the seasons. It was improved by the construction of two straight, parallel, rip-rap jetties, of which the southerly one was 6,800 and the northerly one 6,500 feet long and 1,000 feet apart, capped with random stones weighing several tons, roughly placed from trestles, and afterwards maintained by derrick barges. The work was begun in March, 1890, and completed about the end of 1892, at a cost of $2,221,000 United States currency.

The fluvial discharge from the high plateaus is rapid and at its maximum reaches 215,000 cubic feet per second, having a velocity through the jettied channel of 7 feet per second and a slope of 10 inches per mile. The cross-section of the stream is 19,460 square feet. In heavy floods the ratio of sediment to water is 1 to 400, in ordinary stages it is 1 to 1,300, in bulk. There is a diurnal tide of 15 inches and a littoral drift to the southward, especially during the winter season. The flood of the summer of 1893 scoured out some 1,202,000 cubic yards, and the total removed amounted to about 4,000,000 cubic yards, resulting in a depth of 26.5 feet at mean low water, which was fairly well maintained by dredging at intervals.

On June 24 it was further reported as from the British Consul: "The condition of the harbor at Tampico leaves much to be desired in the way of dredging. The dredge is too small to keep the channel clear. The depth on the bar does not permit vessels drawing over 22½ feet to enter. The Government contemplates extending the jetties and their reconstruction, hoping to secure 30 feet."

The Tampico jetties, as well as those at the South Pass, were under the immediate construction of the world-renowned maritime engineer, Mr. Elmer L. Corthell, and are among the most satisfactory works of their class, both as to design and results, yet it would seem that even at the mouths of large streams bearing sediment they have their limitations and are not automatic and self-maintaining.

NOTES ON THE COLUMBIA BAR, OREGON.

(Data Compiled from Report of Chief of Engineers, 1911.)

In 1884 the first project was made for a half-tide jetty, 4½ miles long, on the south side, to be built of rubble stone deposited from a trestle. Temporary result, 31 feet, during readjustment of equilibrium. Cost, when raised to high tide with four groins added, was $1,968,753. Completed in 1895, followed by rapid shoaling, to arrest which the project was modified in 1903 by the proposed extension of the south jetty 2½ miles, the building of a north jetty, and by dredging. In 1901 the depths had shoaled to 21 feet and the channel had drifted some two miles to the northwest.

The estimated cost to secure 40 feet was $3,715,000. This project was again revised to raise the jetty to mid-tide level, in 1909, at a cost of $3,529,300, and to make it 25 feet wide at that level. In some places it is in 39-foot depths, thus "requiring an enormous increase in the amount of rock." Between September 20, 1910, and June 30, 1911, the dredge worked on the bar 62 days, removing 212,080 cubic yards of material. Project is 85 per cent. completed.

The survey of June shows the channel to have shifted about 2,500 feet to the northwest and that the depths vary from 25 to 27½ feet, an increase of 1 foot over last year. The mean tide is about 7.4 feet.

"The life of the trestle is very uncertain. . . . It is believed that the contraction of the entrance by the north jetty may be followed by scouring along the north side of the south jetty, and that for the maintenance of the south jetty two more groins should be provided, each about 500 feet long."

The total appropriations since June 13, 1902, aggregate $7,901,852.24.

From the above it appears that the actual gain in depth by jetty and dredging is about 5 feet, in some ten years, giving an average cost per foot of $1,580,370, and that the crest of the bar is still two miles beyond the outer end of the extended jetty, while the channel is not fixed in position, but is still drifting rapidly northward, and the cut dredged has less depth than before it was begun. "The outer 24-foot contour has advanced some 3,000 feet since 1902, and the depths of 50 feet in that year had shoaled to 24 feet by 1909. On the southerly side of the jetty the 24-foot curve had advanced about 4,000 feet within two years, or about twice the length of the jetty extension in the same time, and large deposits had been made in the throat of the entrance between the jetty and Peacock Spit."

The proposed north jetty will merely arrest the northwardly moving littoral drift and cause more rapid advance of the bar, as has frequently happened elsewhere.

THE REACTION BREAKWATER.

As early as 1869, the writer, while stationed in Texas as United States engineer officer in charge of the district, began his investigations on these harbor questions, and after extended researches on snow-drifts, sand-dunes, and river currents, and also repeated surveys of shifting inlets, a system of works was evolved whereby a portion of a single, curved, resisting medium was so designed as to protect the bar-crossing from the resultant littoral drift, yet at the same time admitting the full tidal prism to the interior compartments, confining the effluent tides to a contracted path, and also causing a *reaction* by a constant change of direction, accompanied by scour and lateral transportation, and with no bar advance nor material interference with the prevailing littoral movements. By this means of connecting the deep water within and beyond the bar by a visible aid to navigation, under the lee of which there could be no shoaling because of the activities of the effluent waters, the current automatically constructed its own channel.

At Aransas Pass, Tex., the plan was tested on a practical scale by putting into position in twelve years instead of *one* a breakwater guaranteed to create a 20-foot channel across a bar of from 6 to 8 feet in depth.[2] The automatic channel has been secured by the feeble diurnal tide of 14 inches, at a cost of *less than one-fourth* of the amount estimated for the two-jetty channel. A terminal harbor is now being constructed with modern facilities for a commercial emporium on the Gulf for more than a million square miles of tributary territory.

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[2] JOURNAL FRANKLIN INSTITUTE, February, 1908.

The pass now has 23 feet of water 300 feet in width in the Gulf.[3] This is three feet more than the Government proposed to secure by two jetties with dredging at an estimated cost of $2,052,542 for dredging alone, thus effecting a saving of over $1,616,078.

In other cases than the above, these methods are now being applied whereby bar and river channels are maintained automatically by the action of natural forces, and without recourse to constant dredging and stirring and other mechanical methods of removal.

The Conservation of Vital Resources.—To endeavor to arouse a national sentiment for the conservation of vital resources two Congresses have this year been organized and will be held this month. The Fourth National Conservation Congress will take place at Indianapolis, Ind., from October 1 to 4, inclusive, and the above subject has been taken for its main theme. Coincidently, the First Coöperative Safety Congress will meet at Milwaukee, Wis., from September 30 to October 5. This latter is under the auspices of the Association of Iron and Steel Electrical Engineers, which will hold parallel and joint sessions with it.

Density of Solid Substances. J. JOHNSTON and L. H. ADAMS. (*Amer. Chem. Soc. Journ.*, xxxiv, 563.)—A new form of pyknometer has been designed capable of determining the density of solids to within 0.02 per cent. Powdering a homogeneous crystalline substance free from unsoundness does not affect its density. Very high hydrostatic pressure has no permanent effect on the density of homogeneous crystalline materials. On metals, pressure first increases the density by closing the pores or interstices, after which the density decreases, sometimes below the original value. Subsequent annealing increases the density. Contrary to Spring's observations, bismuth decreases in density after deformation. A comparison of the data obtained with the observations of Beilby indicates that the amorphous phase is similar to an undercooled melt. The result of deformation, therefore, should be to produce a change of density in the same direction as that produced on fusion, and this is the case with all metals except bismuth.

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[3] *Shipping Illustrated,* February 3, 1912. See *Cassier's Magazine,* April, 1909, for paper on "Barriers to International Trade."

Abuses of the United States Patent System. L. H. BAEKELAND. (*J. Ind. Eng. Chem.*, iv, 333.)—The difficulty and expense of enforcing patent rights in the United States courts are very great, and a patent is often worthless to a man of limited resources. Successful litigants seldom recover damages for infringement, or not sufficient to cover legal expenses. The wealthy corporations are able to bluff their weaker competitors or to crush them by prolonged litigation, and the money so spent is ultimately paid by the consumer. Separate final decisions are given by each of the nine Circuit Courts of Appeal, and these decisions are not always in harmony. Evidence is not taken by testimony in open court, and in one case 36 large octavo volumes of printed testimony, containing much repetition and irrelevant matter, were submitted. The proceedings in "interference" cases involving the respective rights of inventors applying concurrently may be prolonged for years. The reforms suggested are similar to those proposed by W. F. Rogers.

Mercury Production of the United States in 1911. ANON. (*Oil, Paint and Drug Reporter,* June 24, 1912.)—The production of mercury in 1911 in the United States was the greatest since 1907, the total output being 21,256 flasks of 75 pounds each, valued at $927,989, against a production of 20,601 flasks, valued at $958,153, in 1910. California was the greatest producer in 1911, with 18,860 flasks, valued at $867,749, and the remainder came from Nevada and Texas. The annual domestic consumption appears to be from 18,000 to 21,000 flasks, or about equal to the domestic production. The decrease of domestic stocks, and higher prices in 1911, caused the heaviest importation of mercury in many years. On the other hand, exports of mercury decreased from 1,923 flasks in 1910 to 291 flasks in 1911.

Gold, Silver, and Iodine in Sea Water. H. S. BLACKMORE. (*Cass. Mag.,* xli, 3.)—The value of the gold in a cubic mile of sea water is $93,184,000; that of the silver is $8,644,600, and that of the iodine, $62,003,200. It is suggested that if a suitable precipitant for these elements could be found it would be possible, by means of huge tanks automatically filled at high water and emptied at low tide, to realize large sums by their recovery. The gold and silver seem to be held in solution by the iodates and iodides of sodium, potassium, calcium, and magnesium, particularly the iodates, which tend to precipitate the gold and silver when reduced to iodides. This precipitation is gradually going on in creeks and inlets where reducing agents, such as occur in sewage. are present; the mud in such inlets contains considerable gold.

THE ELECTRO-PNEUMATIC BRAKE SYSTEM FOR STEAM ROAD SERVICE.[1]

BY

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AND

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THIS equipment is designed for use on motor cars which are of such weight that in order to obtain the desired breaking power and still not exceed the greatest permissible pressures, and leverage ratio, a two-cylinder installation is required. It is similar in many respects to, and has all the important features enumerated in connection with, the previously-described equipment, with the addition of others which are necessary for this class of service.

The maximum cylinder pressure obtainable in service operations is limited by the equalization of the pressure and application chambers. The volume of these chambers is the same for all sizes of equipment, and since the application portion is a measuring valve, governed by air pressures, a uniform cylinder pressure will be obtained throughout the train, *regardless of size of cylinder or piston travel.*

The brake-cylinder pressure is maintained against leakage during service applications in the same manner as provided for in the distributing valve of the well-known " E. T." equipment. The emergency brake-cylinder pressure is determined by the pressure in the main reservoir, and not by that in the pressure chamber. By reducing the effective application piston area exposed to brake-cylinder pressure, the 50 pounds equalization pressure obtained in the application cylinder and chamber is able to hold the application valve in emergency position against 150 pounds cylinder pressure; thus the 100 pounds main reservoir pressure, normally carried, is easily obtained and maintained in the brake cylinders throughout the stop. Since the pressure and application chambers equalize at the same pressure in emergency as in service operation,

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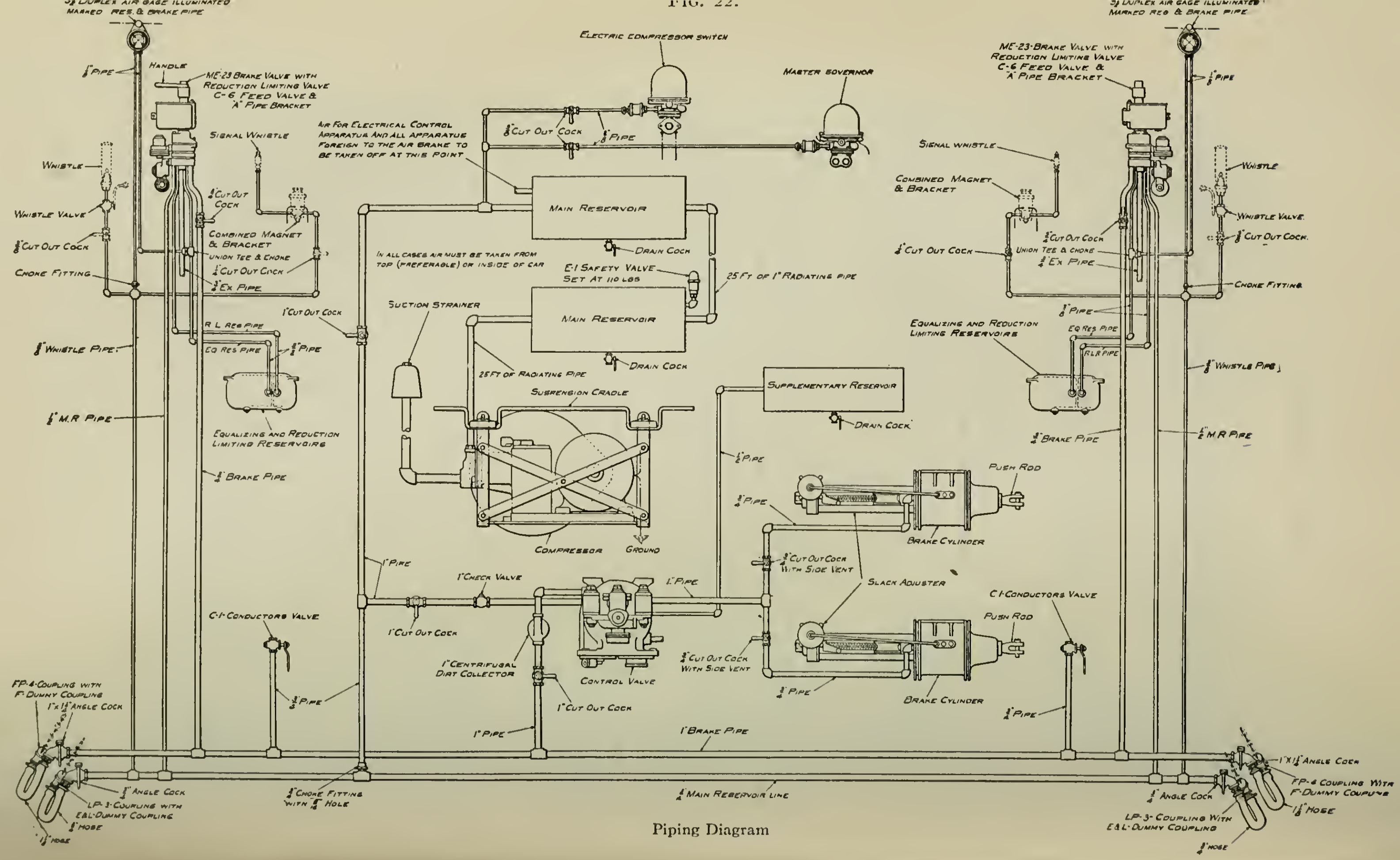
[1] Continued from page 325.

FIG. 22.



Piping Diagram

it follows that the brake-cylinder air can be easily released, because the brake-pipe pressure need only be raised a little higher than the pressure-chamber pressure in order to effect a release.

The pressure chamber is charged from the supplementary reservoir, when the graduated-release feature is operative, up to about five pounds less than normal brake-pipe pressure, so that practically no air is drawn from the brake pipe. This insures a prompt and certain release of the brakes and a rapid recharge and prompt response to successive reductions, which may be made because (1) the air delivered to the brake pipe is all effective in raising its pressure, and (2) the pressure chamber and brake pipe charge at the same rate. With the graduated-release feature inoperative, the supplementary reservoir is cut out, so that the above recharging does not take place, but, owing to the small volume of the pressure chamber, the release is still much more positive and certain than with the older equipments, and this is especially true in cases of long trains, where, with the old equipments, there are large volumes to charge, and, since their source of supply is the brake pipe, necessitates large feed grooves. This makes the rate of increase of brake-pipe pressure on the rear end very slow, since the reservoirs on the head end are taking the air from the brake pipe almost as rapidly as the brake valve can supply it.

Fig. 22 shows the piping diagram of this equipment, which pneumatically consists of a two-compartment reservoir, a supplementary reservoir, and several operating parts embodied in a control valve. These two compartments, the pressure and application chambers, correspond respectively to the auxiliary reservoir and the brake cylinder of the older types of brakes, except that the application-chamber pressure, instead of operating the foundation-brake rigging, actuates the application portion (which is really a measuring valve), and measures, from the main reservoir into the brake cylinders, sufficient air to make the pressure in the latter equal to that in the application chamber.

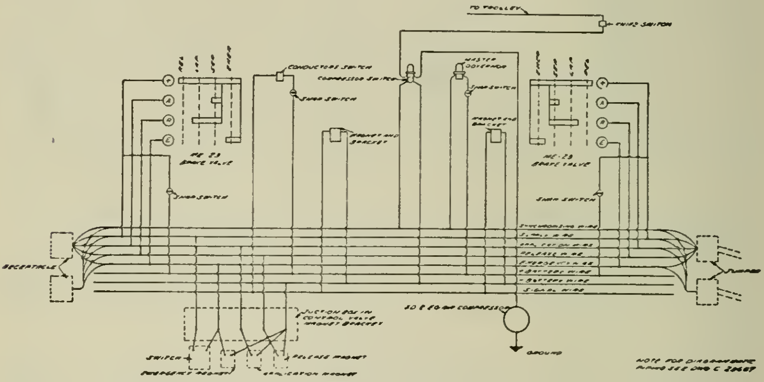
Fig. 23 shows the wiring diagram. Electrically, the equipment comprises the usual application and release magnets, with their attached valves, controlling the electric service application and release of the brakes. In addition to these, there is a third magnet, the emergency application magnet, with its valve, controlling the operation of the emergency parts of the control valve.

The emergency switch and piston might be called the connecting link between the pneumatic and the electric emergency functions of the equipment. It serves as a circuit-closer to produce electrical quick action throughout the train, when originating pneumatically.

The operating valve (Fig. 24) for this equipment is the same as that used in connection with the previously-described equipment.

The novel and distinctive features of this equipment are embodied in the control valve (Figs. 25 and 26), which is comprised of five portions.

FIG. 23.



Wiring Diagram

The Equalizing Portion, in which are: the equalizing piston, equalizing slide valve and graduating valve, which indirectly control the pneumatic service application and release of the brake (through the control of the application-chamber pressure) and the charging of the pressure chamber and supplementary reservoir; the equalizing cylinder cap, which has two positions, one for electric service and one for steam road service. In the latter position, the additional application chamber and the main reservoir charging check valve are rendered operative. The main reservoir charging check valve (operative only when the equalizing cylinder cap is set for steam road service) separates the brake pipe and main reservoir, allowing the former to charge the latter, and preventing a back flow of air from the main reservoir when a brake-pipe reduction is made; the direct- and graduated-release

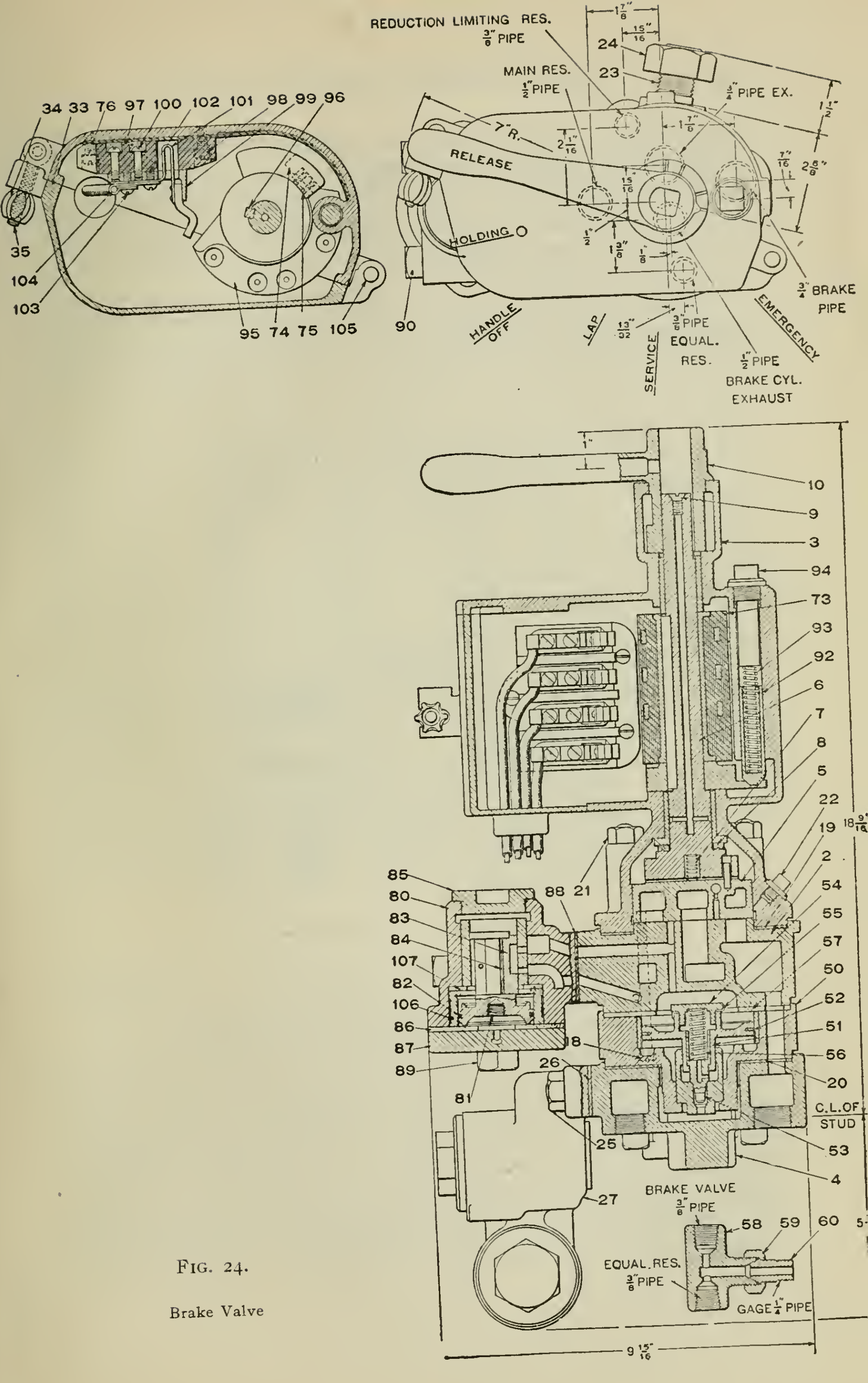


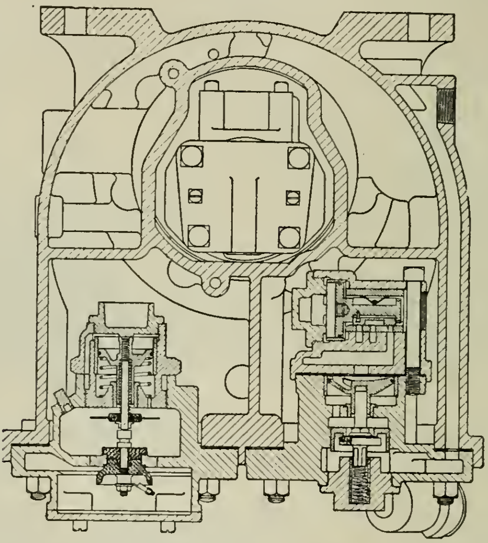
FIG. 24.

Brake Valve

cap, which is to be placed in one position or the other, according as a graduated release of the brake is or is not to be provided for. In the direct-release position, the supplementary charging port and the ports connecting the pressure chamber and the supplementary reservoir are closed, while in graduated-release position they are open.

The Application Portion, in which are: the application piston, application valve and exhaust valve, which directly control the flow of air from the main reservoir to the brake cylinders during service applications and from the brake cylinders to the atmosphere during all releases, and the venting of air from the back of the emergency valve during emergency applications.

FIG. 25.



Control Valve. Cross Section.

The Emergency Portion, in which are: the various parts controlling the quick-action and high emergency pressure functions, viz., the quick-action piston and valve, by means of which brake-pipe air is vented to the atmosphere; the emergency slide-valve piston and slide valve, which control the charging of the quick-action chamber, the flow of air from the quick-action chamber to the quick-action piston and emergency-switch piston, and the venting of air from the back of the application piston; the emergency valve, which, when open, permits main reservoir air to flow direct to the brake cylinders; the protection valve, which automatically produces quick action when the brake-pipe pressure is reduced to a certain predetermined value.

The Emergency Switch Portion, which consists of an emergency switch and piston, which closes the emergency application magnet circuit during an emergency application, at the same time that the quick-action valve is opened (by air from the quick-action chamber).

The Magnet Bracket Portion, in which are: the service application magnet and valve, by means of which the brake-pipe reduction is made at each car; the release magnet and valve, which control the electric release of the brakes; the emergency magnet and valve, which cause the quick-action parts to operate by venting air from the face of the emergency slide-valve piston to the atmosphere; the electric service port check valve, which prevents loss of brake-cylinder pressure during an emergency application, which would otherwise take place past the service application magnet valve into the brake pipe, and thence past the emergency application magnet valve and the protection valve exhausts to the atmosphere; the magnet valve cut-out cap, by means of which either or both of the application magnets may be cut out or cut in; a junction box, which permits of the wiring connections being easily and neatly made, and also greatly facilitates the making and breaking of these connections in inspection and maintenance work, as well as protecting them from damage.

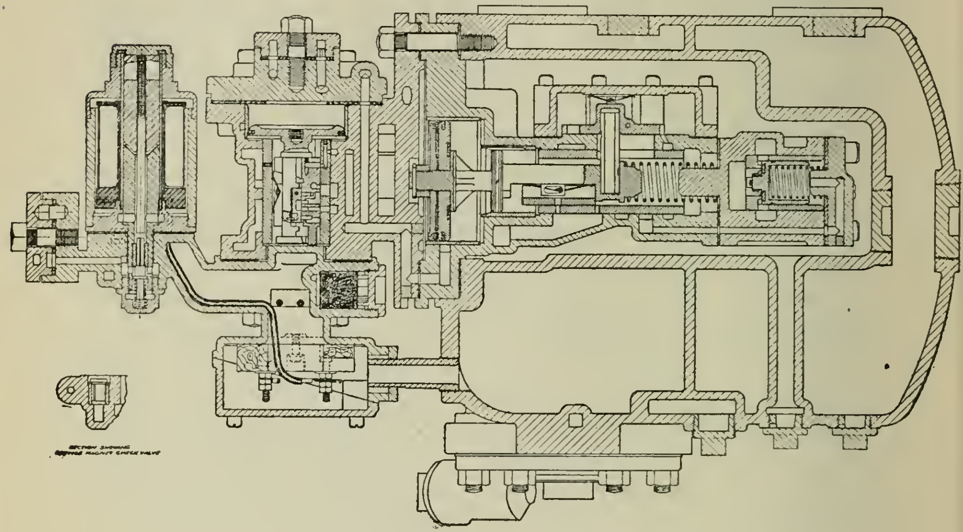
OPERATION OF THE EQUIPMENT.

Charging Position.

Air from the brake pipe enters the valve as indicated on Fig. 27 and flows past the quick-action valve, which is seated, and then to the face of the protection valve, which will remain seated until a certain predetermined pressure is reached, when it will be moved very quickly to its closed position. Air then flows to the face of the emergency slide-valve piston, forcing it to release (if not already there), then through the feed groove into the chamber back of this piston and to the quick-action chamber. Air from the brake pipe is in communication with the service and emergency magnet valves by way of the strainer and magnet cut-out cap (shown in normal position).

Brake-pipe air also flows to the face of the equalizing piston, forcing it with its valve to release position (if not already there). The chamber in front of the equalizing piston is in communication with the pressure chamber through two channels: first, by way of the feed groove and slide-valve chamber, and, second, direct, through the direct- and graduated-release cap.

FIG. 26.



Control Valve—Longitudinal Section

The supplementary reservoir is charged through the equalizing slide valve from the slide-valve chamber. The feed groove and the additional pressure chamber charging port (closed when the direct- and graduated-release cap is set for direct release) bear the same relation to the combined volumes of the pressure chamber and the supplementary reservoir as the feed groove does to the pressure chamber, consequently the time required to charge the equipment will be the same whether the supplementary reservoir is cut in or not.

Main reservoir air enters the valve as indicated and flows from the application valve chamber to the back of emergency valve, and also to the face of this valve, which will then be balanced and held seated by its spring.

ELECTRIC SERVICE APPLICATION.

When an electric application of the brakes is desired, the brake-valve handle is moved to the service application position, which is the same for both electric and pneumatic operation, but in passing from release position to service position, lap position is passed over, in which position the release magnet circuit is closed, energizing this magnet, which, in turn, seats the release magnet valve. This magnet valve is held closed in service position as well, and, in addition, the application magnet circuit is closed, energizing this magnet, which, in turn, opens the service application magnet valve. This allows brake-pipe air to flow past the electric service port check valve into the brake cylinder. The electric service application port is choked down to the proper size to permit of a rate of brake-pipe reduction which will cause the equalizing piston, graduating valve, and slide valve to move to service position. But this rate of reduction is not rapid enough to move the emergency slide-valve piston and its slide valve, since, under these conditions, the quick-action chamber pressure can reduce through its feed groove as rapidly as the brake-pipe pressure is being reduced. This insures the desired service application and prevents the possibility of undesired quick action.

The first movement of the equalizing piston and graduating valve toward service position closes the feed groove, the supplementary reservoir charging port, opens the service port, and allows the cavity in the graduating valve to connect the resistance increasing cavity to atmospheric pressure. This increase in the amount of the under surface of the slide valve, which is exposed to the atmosphere, increases the resistance which has to be overcome before the equalizing slide valve can be moved. This feature was explained fully in connection with the previously-described equipment (second instalment of paper).

The air flowing into the application cylinder from the pressure chamber will move the application piston to application position, carrying with it the application valve and exhaust valve. The exhaust valve closes the exhaust ports and prevents any flow of air from the exhaust-valve chamber and the brake cylinders to the atmosphere. The application valve opens the application port and allows main reservoir air to flow into the exhaust-valve chamber, and thence into the brake cylinders. The pressure in

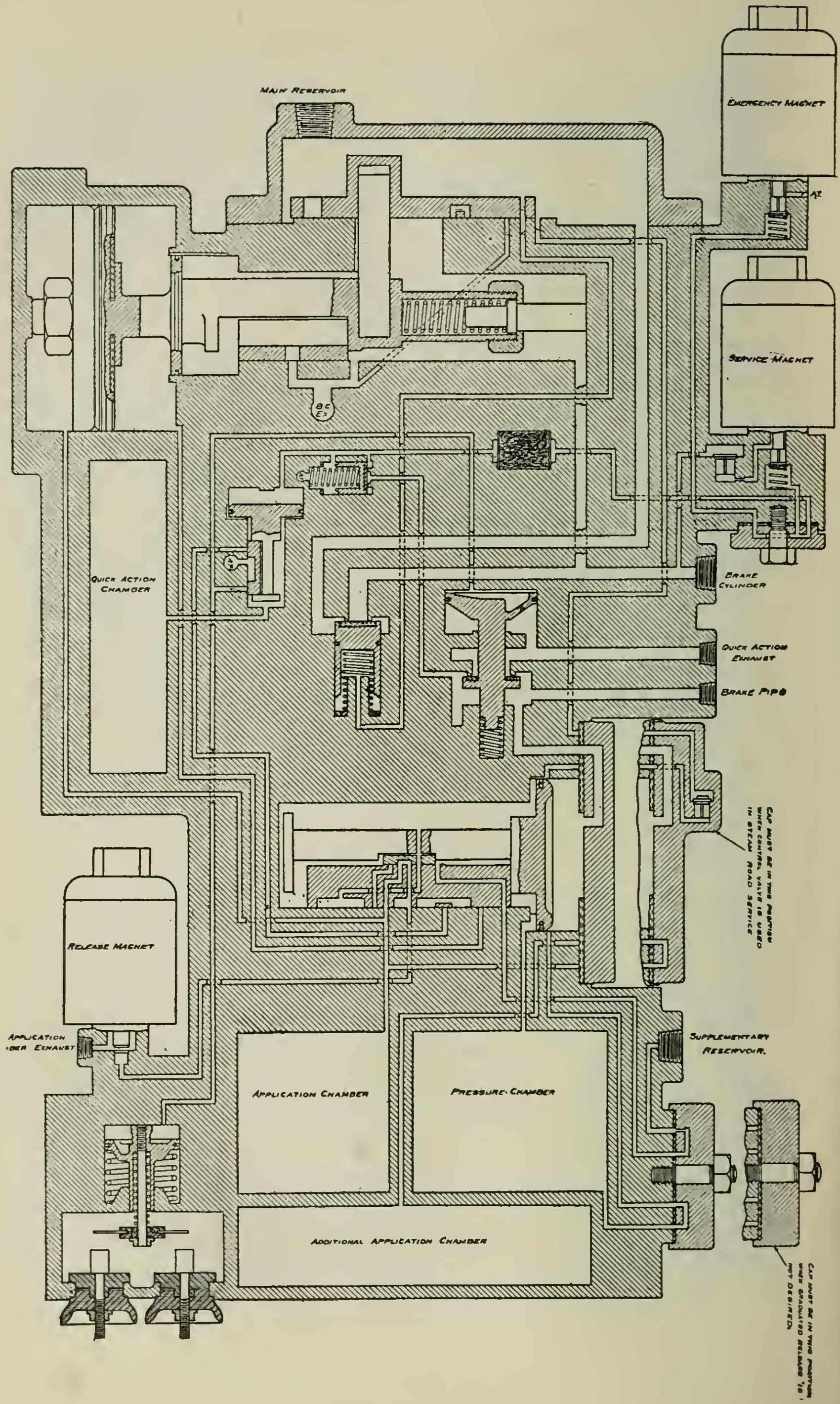


FIG. 27.

Control Valve—Diagrammatic Assembly

exhaust-valve chamber and in the chamber back of application piston are kept the same in service applications, since these chambers are connected by feed groove in small application piston bush.

The pressures in the application cylinder and chamber will be increased until they have equalized with the pressure chamber (the volumes of these chambers being so proportioned that with 70 pounds in the pressure chamber an equalization of 50 pounds is obtained), or (in case a full service reduction in brake-pipe pressure is not made) the pressure-chamber pressure is reduced to a point slightly lower than that in the brake pipe. In the latter case, the equalizing piston and graduating valve will be moved back from service position until the equalizing piston rests against the slide valve in service lap position, thus closing the service port, which prevents a further building up of application-cylinder pressure.

The flow of air from the main reservoir to the brake cylinders continues until the pressure in the brake cylinders, and consequently in the exhaust-valve chamber, is equal to that in the application cylinder, when the application piston graduating spring will move the piston and valve back to service lap position, in which position the application port is closed. The pressures on both sides of the application piston are balanced, and consequently if there be any drop in brake-cylinder pressure, due to leakage, the application piston will be moved toward the lower pressure, and cause a slight renewal of pressure in the exhaust-valve chamber and brake cylinders; thus the air lost from the brake cylinder by leakage is automatically replaced by this operation of the application piston and valve, and the brake-cylinder pressure maintained at an equality with that being held in the application cylinder. The lost motion between the application piston and the exhaust valve allows the application piston and valve to be moved back and forth in thus maintaining brake-cylinder pressure without moving the exhaust valve.

The service application magnet may be held energized, thus holding the magnet valve open and allowing the equalization of the pressure chamber with the application chamber and application cylinder (giving a full-service application of the brakes), or it may be energized for only a portion of the time necessary to cause a full-service application, and thus cause only a partial application of the brake, after which the parts will be moved to service lap position, as above mentioned. The energizing of the service magnet may be repeated several times, each time causing a further increase in the brake-cylinder pressure, corresponding to the amount of brake-pipe reduction, until the final equalization of the pressure chamber and the application chamber and cylinder.

The application port is larger than the port leading from the exhaust-valve chamber to the brake cylinder. Therefore the former does not need a full opening to supply the latter, and, consequently, the application valve will never move past its service position far enough to allow the port in the application valve to connect the ports leading to the atmosphere and to the back of emergency valve (as is done in emergency).

ELECTRIC EMERGENCY APPLICATION.

With the brake-valve handle in emergency position, the emergency magnet circuit is closed, energizing this magnet, which, in turn, opens the emergency application magnet valve and allows brake-pipe air to flow through the emergency magnet valve port to the atmosphere. The emergency exhaust port of the brake valve is also open; but, since the electric current travels so much faster than the reduction of air pressures, it is the electrical emergency that controls and applies all the brakes in the train, practically simultaneously. The emergency magnet valve port is of such size as to permit of a rate of brake-pipe reduction which will cause the emergency slide-valve piston and its slide valve to move over to emergency position, and also cause the equalizing piston and its slide valve to move over until the piston rests against its cylinder cap gasket (in which position the same port openings prevail as in service application).

With the emergency slide-valve piston and slide valve in emergency position, the quick-action chamber air flows to the quick-action piston, thus forcing the quick-action valve open, thereby venting brake-pipe air to the atmosphere (which causes a sudden local brake-pipe reduction that starts pneumatic quick action), and to the emergency switch piston, thereby closing the emergency switch, which serves as a circuit-closer to cause instantaneous quick action throughout the train when originating pneumatically.

The quick-action valve will remain open and the emergency switch closed until the quick-action chamber air can drain to the atmosphere, through the small drilled port in the quick-action piston, after which they will be returned to their normal positions by their springs.

With pressure-chamber air flowing into the application chamber and cylinder, and the chamber back of the application piston connected to the atmosphere (by way of the equalizing slide valve, and the cavity in the emergency slide valve), the application piston will be moved over until the leather seal on its inner side rests against the seat on the end of the small bush. In this position the feed groove in the small bush has been cut off, thus separating the exhaust-valve chamber from the chamber back of the application piston. The application valve chamber and exhaust-valve chamber are connected through the application port, the same as in service, and, in addition to this, another port in the application valve connects the chamber back of the emergency valve to the atmosphere; thus the emergency valve, with main reservoir pressure on the face and atmospheric pressure on the back, will open and make a large direct connection between the main reservoir and the brake cylinders, and allow these pressures to equalize in a very short time. With the chamber back of application piston connected to the atmosphere, the application piston area exposed to application-chamber pressure is about three times that exposed to exhaust-valve chamber pressure, consequently the 50 pounds equalizing pressure of pressure and application chambers is able to retain a brake-cylinder pressure of 150 pounds, which would be more than the highest possible pressure in emergency, since the compressor governors are set to cut out at 100 pounds.

ELECTRIC RELEASE AFTER SERVICE APPLICATION.

With the brake-valve handle in release position, the release magnet circuit is open, de-energizing this magnet and allowing the release magnet valve to open. The brake-pipe port in the brake valve is also open, and is restoring the air in the brake pipe to its initial pressure. This increase in brake-pipe pressure forces the equalizing piston and its slide valve back to their release positions, in which the application-chamber and application-cylinder air is exhausted to the atmosphere by way of the equalizing slide valve, graduating valve, and release magnet valve. With the air in application cylinder exhausting to the atmosphere, the higher brake-cylinder pressure in the exhaust-valve chamber (back of application piston) will force the application piston back from lap position to release, carrying with it the exhaust valve. The latter will open the exhaust port and allow the brake-cylinder air to flow to the atmosphere.

ELECTRIC RELEASE AFTER EMERGENCY APPLICATION.

After an emergency application has been made, the quick-action valve will remain open and the emergency switch closed until the quick-action chamber air has drained to the atmosphere through the small drilled port in the quick-action piston, after which the quick-action valve will be closed and the emergency switch opened by their respective springs.

With the quick-action valve closed and the brake-pipe pressure being restored, the protection valve will be the first to go to normal position (release), which will, in turn, admit air to the face of the emergency slide-valve piston, forcing it to release and charging the quick-action chamber as described under "Charging." Brake-pipe pressure has also been built up on the face of the equalizing piston, forcing it, with its valves, to release position, which will, in turn, permit the exhaust of application cylinder and chamber air and the return of the application piston and its valves to release position, and, finally, the emergency valve will be balanced by the opening of the ports leading to the back and to the front of this valve, and will be seated by its spring, closing the direct communication between the main reservoir and the brake cylinders, after which the high pressure brake-cylinder air will exhaust to the atmosphere.

GRADUATED RELEASE.

The release of the brakes may be graduated by moving the brake-valve handle to release for a few seconds and then back to lap position. The brake-pipe charging port of the brake valve is open in release position, causing a slight increase in the brake-pipe pressure and moving the equalizing parts of the control valve to release position. (In lap position of the brake valve the brake-pipe charging port is closed, consequently only a few pounds increase in brake-pipe pressure will result.) Also in release position of the brake valve the release magnet circuit is de-energized and the release magnet valve is held open by its spring, thus allowing the air from the application chamber and cylinder to flow through ports in the equalizing slide valve, cavity in the graduating valve, and past the release magnet valve to the atmosphere. The application piston and valves will then be returned to release position, making connection from the brake cylinders to the atmosphere.

But with the equalizing parts in release position, and the direct and graduated release cap in the position marked "Graduated Release," the graduated release port is open and connects the supplementary reservoir and the pressure chamber; since the former volume is not used in service operations, it will still have its initial pressure. Supplementary reservoir air flowing back into the pressure chamber will quickly raise the pressure in the latter slightly in excess of that in the brake pipe, and, consequently, it will move the equalizing piston and graduating valve to graduated release lap position, in which the graduated-release port is closed, thus preventing a further increase in pressure-chamber pressure, and a further decrease of application cylinder and chamber pressure. Brake-cylinder air will continue to exhaust to the atmosphere until its pressure is slightly lower than that being held in the application cylinder, when the application piston and exhaust valve will be moved back to lap position.

A further reduction of brake-cylinder pressure cannot now be made until the brake-pipe pressure is further increased, and the equalizing piston and graduating valve moved to release position, when the above operation will be repeated. This graduation of the release may be repeated until the brake-pipe, pressure-chamber and supplementary reservoir pressures are equalized, when the valves will remain in release position and give the final release of brake-cylinder air.

Even with the direct- and graduated-release cap in "direct release" position (which closes the supplementary reservoir connection to the pressure chamber), it is always possible (when the electric features are operative) to graduate the release of the brake by means of the release magnet valve alone, if the brake-valve handle is moved alternately to release position and back to lap (the equalizing parts of the control valve remaining in release position).

PNEUMATIC OPERATION.

In case any of the electric features should be inoperative, through loss of current or other causes, the equipment may be operated as any of the older types, the brake-pipe reductions then being made by means of the brake valve alone (the positions of the brake valve handle being the same for both electric and pneumatic operation).

PNEUMATIC SERVICE APPLICATION.

With the brake-valve handle in service position, the preliminary exhaust port in the brake valve is opened, allowing the equalizing piston to lift and produce a rate of brake-pipe reduction sufficiently rapid to move the equalizing piston, graduating and slide valves to service position. The rate of reduction as fixed by the brake valve is, however, not as rapid as that at which the quick-action chamber pressure can be reduced through its feed groove into the brake pipe (thus positively guarding against undesired quick action).

The operation of the various valves is now the same as previously described under "Electric service application."

PNEUMATIC EMERGENCY APPLICATION.

With brake-valve handle in this position, the emergency exhaust port is open and permits of such a rapid rate of brake-pipe reduction that the quick-action chamber pressure cannot reduce as rapidly through its feed groove as the brake-pipe pressure is being reduced through the brake valve. Consequently, the emergency piston and its slide valve are moved to their emergency positions. The equalizing piston has also moved (carrying with it the slide valve and graduating valve) against the cylinder-cap gasket.

The operation of the various valves is now the same as previously described under "Electric Emergency Application."

PNEUMATIC GRADUATED RELEASE.

This is accomplished in the same manner as previously described, except that the release magnet valve is open at all times, and the graduated release controlled entirely by the pneumatic parts.

PROTECTION FEATURE.

In case there is excessive leakage, after a full-service application has been made, which will reduce the break-pipe pressure to a certain predetermined value the protection valve will be forced open by its spring, thus connecting the face of the emergency slide-valve piston to the atmosphere, past the protection valve seat, and producing a rate of brake-pipe reduction that will cause the emergency piston and slide valve to move to emergency position, thus causing quick action as previously described.

STEAM ROAD SERVICE.

Cars having this equipment may at times be used in steam road trains in connection with standard steam road cars, upon which the braking power is calculated on the old basis of 90 per cent. on 60 pounds cylinder pressure (equivalent to 75 per cent. on 50 pounds), consequently cars with E-11 control valve, having their braking power calculated on the basis of 100 per cent. for 50 pounds cylinder pressure, some means must be used whereby this difference may be eliminated, or at least reduced considerably, if the desired uniformity in service-brake operation is to be obtained.

This is accomplished by using, in such cases, an additional application chamber, thus increasing the volume of the application chamber so that from 110 pounds pressure carried (which is used in almost all steam road passenger service) the pressure and application chambers will equalize at 70 pounds.

This means that a lower brake-cylinder pressure, and, consequently, less braking power, is obtained for a given brake-pipe reduction. As a matter of fact, the control valve equipment under these circumstances actually obtains ¼ of 1 per cent. less braking power per pound of brake-pipe reduction than the ordinary automatic brake in general use in steam railway service, and 5 per cent. for a full-service brake-pipe reduction (20 pounds), the steam car thus having the higher braking power.

In emergency operation, the E-11 equipment car set for steam road service will obtain a little above 200 per cent. braking power and retain it throughout the stop, while the steam road car will obtain 127 per cent., and which will gradually be reduced to 90 per cent. as the car is retarded, due to the action of the high-speed reducing valves.

This inequality can be tolerated in emergency, because then "to stop" is the most important factor.

When a car equipped with this valve is used in steam road service (for example, when being transported from the manufacturer to its destination) the equalizing cylinder cap must be turned to the proper position for this service. In this position the ports are so connected that when a brake application is made air flowing from the pressure chamber into the application chamber and cylinder can also flow into the additional application chamber. This extra volume added to the application chamber increases its volume to such an extent that now, with the pressure chamber charged to 110 pounds, the pressure-chamber pressure will equalize into the application chamber and cylinder at 70 pounds; thus the service cylinder pressure is limited to 70 pounds, and the emergency-cylinder pressure to something less than 110 pounds, which is the brake-pipe pressure carried and the maximum obtainable in the main reservoir; therefore the cylinder pressure cannot be built up high enough to give excessive braking power.

Again, in steam road service, we have no main reservoir line to supply air for braking this car; therefore, the main reservoir on this car will be charged from the brake pipe. Air from the brake pipe flowing to the face of equalizing piston is now free to flow past the main reservoir charging check valve and thence to the application-valve chamber and to the main reservoir. This reservoir charging port is of such size that the main reservoir in charging cannot take the air from the brake pipe fast enough to affect the brake operations; and since it separates the brake pipe from the main reservoir, in all except release position, the valve must be in the latter position before the reservoir can be charged.

Since in steam road service there is no means of obtaining electric current for the electric operation of the brake, it will be evident that under these conditions the equipment will be operated pneumatically.

(*To be continued.*)

Cerium. ANON. (*Brass World,* viii, 8, 294.)—Metallic cerium is a white metal resembling iron in color and tin in hardness. It can be readily rolled into sheet or drawn into wire. Its specific gravity is 6.92, or about that of zinc. It melts at 635° C., or practically at the same temperature as aluminum.

NOTES FROM THE U. S. BUREAU OF STANDARDS.

ON A MODIFIED FORM OF STABILITY TEST FOR SMOKELESS POWDER AND SIMILAR MATERIALS.[1]

By H. C. P. Weber,
Assistant Chemist, Bureau of Standards.

THE stability test is a form of the so-called explosion test. In the German test the sample is heated to 135° C. and the length of time is noted until the sample explodes. In the other form of high temperature test the temperature of the sample is gradually raised until a point is reached at which the sample explodes, or at least decomposes with explosive violence.

The decomposition of products of this class is exothermic and autocatalytic, and the temperature of the decomposing material may be few or many degrees removed from the temperature of the heating bath. The amount of this difference will depend on a number of variables, such as the mass of the material, its heat conductivity, and the heat conductivity of the systems used for test. These factors enter into the German 135° test as well as into the ordinary high temperature explosion test. In the former the time will vary with the heat insulation; in the latter the explosion temperature will vary with the rate of heating.

The proposed test consists in the determination of a time temperature explosion curve. The samples are chosen small enough to practically eliminate the factor of heat conductivity of the sample. The apparatus consists of a heating bath which may be kept at various constant temperatures. For this work the temperatures chosen were 200° C., 180° C., 170° C., 160° C. The length of time necessary for a sample to explode is determined with the aid of a stop-watch at one constant temperature, and then at the next, and so on. The results are plotted in a curve with time and temperature as ordinates and abscissæ.

That the results are reproducible to within a few per cent. is shown by numerous repetitions. After the curve has been plotted by means of three or four points, determinations made at intermediate temperatures fall on the curve. The curve is, therefore, characteristic of the sample. It represents, in effect, the rate of change of decomposition velocity with change of temperature, and as such is an index of the stability of the powder.

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[1] Abstract of paper to appear in the Bulletin of the Bureau of Standards.

Inspection of the curves shows that for stable powders there is a pronounced bend, while the ratio of explosion periods at 200° C. and 160° C. is at least 2:9. In the unstable powders this ratio falls as low as 2:3 and the irregularities become greater. It also becomes evident that one explosion temperature, even if time is considered, does not give much information.

It is possible that with sufficient accumulated data the test may throw some light on the actual effect of a stabilizer on the natural decomposition velocity of powders.

A short résumé of the literature on stability tests is given.

THE ATOMIC WEIGHT OF BROMINE.[1]

By H. C. P. Weber.

THE National Bureau of Standards has just sent to press the results of the work of H. C. P. Weber on "A New Determination of Atomic Weight of Bromine." A considerable amount of work has been done in order to determine the atomic weight of bromine, and the oft-repeated comparison of the atomic weights of silver and bromine makes it seem that this ratio is known with considerable accuracy. The value accepted for bromine, however, rests almost entirely upon that of silver, and it is of interest and importance to obtain a ratio between it and some other element. For chlorine a number of determinations of the ratio of hydrogen to chlorine in hydrochloric acid have been made, both by purely physical and by chemical methods. For bromine similar comparisons have not been made. Since the determination of the ratio chlorine: hydrogen was carried out with reasonable ease it seemed probable that the method might be advantageously applied for the purpose of determining the ratio between hydrogen and bromine.

The ratio of the atomic weights of hydrogen and of bromine is obtained by determining the amount of bromine which a weighed quantity of hydrogen will remove from potassium bromplatinate. The hydrobromic acid formed is also weighed. From ten determinations twenty values are obtained giving the ratio H : Br equal to 1 : 79.306^6 with a probable error of ± .0014. Taking the atomic weight of hydrogen as 1.00779 (o = 16) the atomic weight of bromine is *79.924*.

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[1] Abstract of forthcoming scientific paper to appear in vol. 9 of the Bulletin of the Bureau of Standards.

THE TESTING AND PROPERTIES OF ELECTRIC CONDENSERS.[1]

In the testing of condensers over a period of years much information has been collected, only a part of which is at present available to the public. Also, a large amount of work has been done elsewhere, which has appeared in various publications. It is the purpose of this circular to collect together the important facts concerning condensers and to present them as a connected whole. The different kinds of condensers are described, their properties discussed, and the most satisfactory methods of testing indicated.

On account of their importance as standards, mica condensers are treated at considerable length. The effect of absorption on the phase angle and effective capacity is discussed in considerable detail, and many results are given showing the values that may be expected for good mica condensers. Also, a standard method of test is indicated.

Paper condensers are similar in their behavior to mica condensers, but the effect of absorption is much more marked. Also, in some paper condensers the resistance of the plates affects the phase angle in a very pronounced manner. Results on a number of commercial condensers are given.

A TUBULAR ELECTRODYNAMOMETER FOR HEAVY CURRENTS.[2]

By P. G. Agnew.

The field "coil" of the instrument consists of two coaxial copper tubes, thus giving a circular magnetic field in the space between the tubes. On direct current the distribution of the current is assumed to be uniform over the cross section of the tubes, but on alternating current, as is well known, the current is crowded toward the outside of the inside tube and toward the inside of the outside tube, and the amount of this change of distribution depends upon the frequency. But if we have axial symmetry the magnetic field at any point is independent of the current distribution. For there is no magnetic field between the tubes due to the outside tube, and the field at any point due to the current in the inside tube symmetrically distributed about the axis depends only on the distance of the point from the axis, and, therefore, the total effect is independent of the distribution of current, so long as it is symmetrical with respect to the axis.

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[1] Abstract of Circular of the Bureau of Standards, No. 36, 1912.

[2] Abstract of paper to appear in the Bulletin of the Bureau of Standards, vol. 9.

There are two moving coils astatically placed between the tubes, one above and one below the inner tube, and suspended by a phosphor bronze strip. The common axis of the tubes is placed in a horizontal position in order to permit the use of a vertical suspension. While the distribution of the current is not the same on alternating as on direct current, the magnetic field in the space between the tubes, and hence the torque, is the same.

By passing water through the inner tube, the instrument will carry continuously 5000 ampères, and without water cooling, 1200 ampères. The current-carrying capacity of the moving coils is 0.6 ampère.

Difficulties were at first encountered, due to distortion of the inside tube by differential thermal expansion and by magnetic impurities in the moving coil, but these were finally overcome.

It is of first importance to determine whether the instrument is affected by residual distribution errors. It has been found that a purely electrical test could be used for the exact centring of the inside tube, so that any such residual errors due to imperfections of workmanship could be removed.

At commercial frequencies no error whatever could be detected, due to eddy currents being set up in the tubes by the current in the moving coils.

Measurements of large currents by means of a current transformer whose ratio had been carefully determined were in substantial agreement with the indications of the tubular dynamometer. It is believed that the instrument is accurate to 0.05 per cent.

FRANKLIN INSTITUTE

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, September 4, 1912.*)

Hall of the Franklin Institute,
Philadelphia, September 4, 1912.

Mr. Wilfred Lewis *in the Chair.*

The following report was presented for first reading:
No. 2513.—McKee's Printing Plate and Process.

R. B. Owens,
Secretary.

MEMBERSHIP NOTES.

Elections to Membership.

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LIBRARY NOTES.

Purchases.

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Davy, H.—The Elementary Nature of Chlorine. 1911.
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Dalton, J., and others.—Foundations of the Molecular Theory. 1911.
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Materials of Construction. A text-book of elementary structural design. By James A. Pratt, Mech.E., Director of the Williamson Free School of Mechanical Trades. 196 pages, illustrations, 12mo. Philadelphia, P. Blakiston's Son & Co., 1912. Price 90 cents.

Essentials of Physics for college students. A text-book for undergraduates and a lecture course and reference work for teachers and other students of physics. By Daniel W. Hering, C.E., Ph.D., LL.D., Dean of the Faculty of the Graduate School and Professor of Physics in New York University. 353 pages, illustrations, 8vo. New York, D. Van Nostrand Company, 1912. Price $1.75.

Problems in Physical Chemistry, with practical applications. By Edmund B. R. Prideaux, M.A., D.Sc., Assistant Lecturer in Education, University of

Liverpool. 311 pages, illustrations, 8vo. New York, D. Van Nostrand Company, 1912. Price $2.

The Metallography of Iron and Steel. By Albert Sauveur, Professor of Metallurgy and Metallography in Harvard University. First edition. Variously paged, illustrations, 4to. Cambridge, Mass., Sauveur & Boylston, 1912. Price $6.

National Association of Cotton Manufacturers. Papers presented at the semi-annual meeting held at the Griswold, near New London, Conn., September 9 to 11, 1912. 10 pamphlets, 8vo. Boston, Association, 1912.

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U. S. Bureau of Mines. Bulletin 47. Notes on Mineral Wastes. By Charles L. Parsons. 44 pages, 8vo. Washington, Government Printing Office, 1912.

U. S. Geological Survey. The Production of Mineral Water in 1911, by George Charlton Matson, with a paper on the concentration of mineral water in relation to therapeutic activity by R. B. Dole. Advance chapter from Mineral Resources of the United States, calendar year 1911. 60 pages, 8vo. Washington, Government Printing Office, 1912.

U. S. Forest Service. Bulletin 111. Lightning in Relation to Forest Fires. By Fred. G. Plummer, Geographer. 39 pages, illustrations, 8vo. Washington, Government Printing Office, 1912.

CURRENT TOPICS

Twenty Years' Progress in the Use of Acetylene. V. B. LEWES. (*Times Eng. Supple.*, July 3, 1912.)—Large quantities of acetylene can be safely stored in steel cylinders filled with porous briquettes soaked with acetone and then charged with acetylene under pressure. This dissolved acetylene is largely used on the European continent for railway lighting, and it has many advantages over other illuminants for lighting motor vehicles, for buoys, and for coastal lights. One important development is the use of acetylene in oxy-acetylene burners for autogenous welding; and another application, which promises to considerably increase the demand, is the use of acetylene in self-starting devices for motor vehicles.

Chemical Compounds of Radioactive Elements. H. SCHRADER. (*Phil. Mag.*, xxiv, 125.)—If actinium B is deposited on a platinum wire and the wire heated in a high vacuum (0.003 mm. of air), the radioactive deposit is volatilized at between 600° and 900° C. The volatility of the deposit is increased by previous treatment with chlorine, bromine, hydro-bromic acid, and hydriodic acid. The B and C products of the active deposits of radium, thorium, and actinium condense in air at a temperature several hundred degrees higher than they will in hydrogen. These differences are considered to be due to the formation of chemical compounds.

Cleaning Evaporator Tubes. L. W. THURLOW. (*Intern. Sugar Jour.*, xiv, 328.)—At present there is much lack of system in the selection of suitable means for removing scale from the evaporator tubes of multiple-effect apparatus used in cane-sugar factories. When the scale consists chiefly of calcium oxalate, sulphate, and carbonate, it is of little use applying sodium hydrate (caustic soda), as the surface of the incrustation remains quite hard. Hydrochloric acid alone has but little effect, as this only slightly disintegrates the surface. The most effective means is to treat first with a boiling solution of sodium carbonate, and then with dilute hydrochloric acid. The sodium carbonate should be a 3 per cent. solution, and the hydrochloric acid 1 per cent. Fill the evaporator with a 3 per cent. solution of sodium carbonate and raise the temperature to the boiling point, without a vacuum, as a high temperature is desirable. Every half hour titrate a sample of the evaporator's contents against standard acid, and continue the boiling until the figures are constant; the transformation from oxalate and sulphate into carbonate is then complete. Now run off the liquid in the evaporator, fill it up again with water, and then add the 1 per cent. solution of hydrochloric acid. Heat to boiling and again titrate against standard alkali. The reaction is generally complete within one hour.

Nitrogen in Metals. Anon. (*Brass World,* viii, 8, 270.)—Only recently has the presence of nitrogen in metals been recognized, owing to the difficulty of detecting it by chemical analysis, but it is now known that some metals occlude it eagerly. Its effect on steel has been studied, and it has been shown to lower the strength of aluminum. Pure tantalum has an electrical resistance of 65 ohms, but after heating for one minute in an atmosphere of nitrogen under a slight pressure the resistance is increased to 240 ohms. The filament incandesces with equal brilliancy, and on account of the increased resistance a thicker filament can be used. It is probable that a tantalum nitride is formed during the heating.

The Inventor, the Public, and the Law. W. F. Rogers. (*J. Ind. Eng. Chem.,* iv, 320.)—The United States patent system was framed with the object of encouraging and securing an early disclosure of an invention. The invention is the creation of the individual, and he had always the right to use it himself, or to work it secretly, or to allow the idea to be lost. In return for the disclosure, and for that alone, the State gives him the right to prevent others from working or using the invention for a limited period. By means of the disclosure other inventors are stimulated and enabled to improve on the invention, and the invention becomes available to the public when the patent expires. There is no duty on the patentee to work the invention which he has disclosed, and the proposals in a bill now before Congress providing for compulsory licenses would infringe upon the property rights of patentees as repeatedly laid down by the courts. These provisions are aimed at the large combines which refuse to work some of the patents they hold, but the requirements of the law could be easily met by them, and these requirements would be burdensome to the independent patentees. The present system has secured the establishment of numerous independent factories, but the proposed system would tend to concentrate the useful inventions into fewer hands. The Patent Bar believes that the complaints of the average inventor could be met by modifying the practice of the courts so as to reduce litigation, by empowering some single court to give a final decision covering the whole of the nine circuits, by ensuring that damages for infringement are commensurate with the loss inflicted, by making the information obtained by the Patent Office available to the public, and by modifying the intricate practice in "interference motions."

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DEVOTED TO SCIENCE AND THE MECHANIC ARTS

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NATURAL GAS, WITH INCIDENTAL REFERENCE TO OTHER BITUMENS.*

BY

I. N. KNAPP, M.E.,

Consulting Engineer.

INTRODUCTORY.

Natural Gas is one of the forms of bitumen or hydrocarbon found in Nature, and cannot well be discussed without reference to other forms, such as petroleum, maltha, asphaltum, and the like.

SECTION I.

HISTORICAL SKETCH OF BITUMEN AND ITS SURFACE INDICATIONS.[1]

History fails to record when the first discoveries of bitumen were made by the human race.

It is mentioned many times in the Bible.[2]

The Greek geographer Strabo speaks of the commerce carried

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* Presented at the meeting of the Section of Mining and Metallurgy, held Tuesday, April 9, 1912.

[1] The Tenth Census of U. S., vol. x, chap. i, gives elaborate historical references of bitumen by S. F. Peckham. *Ibid.,* chap. vii, bibliography of bitumen. "Petroleum and its Products," by Redwood, vol. i, sec. i, gives a long historical account of bitumen. The Eleventh Census of U. S. gives elaborate "History of the Use of Natural Gas in U. S."

[2] Genesis, xi, 3; II Maccabees, chap. i, verse 19.

[NOTE.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.]

on to supply the Egyptians with bitumen for the purpose of embalming the dead.

Centuries before the Christian era, Baku was a resort for the fire worshippers of Persia and India, the inflammable gases issuing from the ground being made use of in their ceremonies, and every year thousands of pilgrims travelled to the temples on the peninsula of Apsheron to worship the holy eternal fire. These pilgrims,[3] in later years, arrived in diminishing numbers until 1880, when the Russian Government put a stop to their entry.

At Surakhany, on the eastern edge of the Baku oil field, stands a historic monument or temple on a site visited by Parsees for no less than 2,500 years. Natural gas was led through masonry channels to chimneys at its four corners and burned; also to altars where burnt sacrifice was made.

The Hindoos in the Rangoon district of India long used petroleum to heal disease, to preserve timber, and to cremate the dead.

At the town of "Self-flowing wells,"[4] in western China, natural gas has been used for evaporating brine from time immemorial.

In 668 A. D. petroleum[5] and asphaltic substances were offered to the Court of the Emperor Tenji from the province of Echigo, Japan.

In the same province the utilization[6] of natural gas was projected in 1613.

Sir Walter Raleigh visited[7] the pitch lake of Trinidad in March, 1595, and recorded that he saw "abundance of stone pitch." And in recent years Peckham[8] has reported: "As the bitumen rises in the centre of the so-called lake it is inflated with gas . . . . the gas cavities are of all sizes, some of them very large, and in the aggregate occupy, at a rough estimate, from one-third to one-half the volume of the pitch."

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[3] "The Oil Fields of Russia," by A. Beeby Thompson, pp. 96, 97.

[4] Tz-lin-ching, Province of Szchnan. See *Eng. and Mining Journal,* vol. 69, 1900, p. 193.

[5] Bulletin No. 61, Jan., 1912, Am. Inst. Mining Engineers, p. 104.

[6] *Ibid.,* p. 127.

[7] "Petroleum and Its Products," by Redwood, vol. i, p. 96.

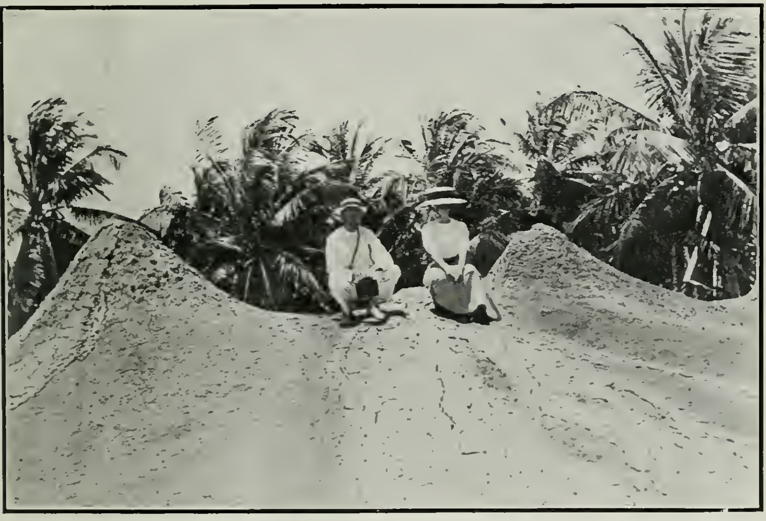
[8] *Am. Journal of Science,* 4th series, vol. i, p. 193.

In the regions of Trinidad[9] and Venezuela, where pitch lakes occur, natural gas is continually forcing up cones of pitch, and they break at the apex and gas issues that may be lighted and will burn sometimes for days.

This phenomenon may be observed not only in the pitch lakes but in the surrounding land asphalt and swamps.

Fig. 1 is a view in Trinidad of typical cones forced up by gas pressure.

FIG 1.



Typical cones formed by gas, Trinidad, B. W. I.

On November 4, 1911, about midday, a fisherman noticed signs of disturbance[10] in the sea off Erin Point, Trinidad.

About 6 P.M. a great column of fire shot up from the water. The principal gas eruption lasted 15 to 20 minutes. There were intermittent flashes of flame during the night.

The next day it was found an island of about 2½ acres had been formed. A landing party found the place still warm, and by laying down boards were able to examine two cones, 12 to 15 feet high, from which gas was escaping. The air was saturated with the odor of sulphur and oil.

The aborigines of our own country were acquainted with petroleum and natural gas springs. The French[11] commander of Fort Dusquesne (now Pittsburgh, Pa.) wrote in 1750:

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[9] Letter of Arthur Knapp, July, 1911.

[10] Account given in *New Orleans Times-Democrat,* Nov. 26, 1911.

> While descending the Allegany we were invited by the Chief of the Senecas to attend a religious ceremony of his tribe. We landed, and drew up our canoes on a point where a small stream entered the river. The tribe appeared unusually solemn. We marched up the stream about half a league, where the company, a large band, it appeared, had arrived some days before us. Gigantic hills begirt us on every side. The scene was really sublime. The Great Chief then recited the conquests and heroism of their ancestors. The surface of the stream was covered with a thick scum, which, upon applying a torch at a given signal, burst into a complete conflagration. At the sight of the flame the Indians gave forth the triumphant shout that made the hills and valleys re-echo again. Here, then, is revived the ancient fire worship of the East; here, then, are the children of the sun.

The existence of natural gas[12] was well known to the earliest explorers of the Kanawha Valley, West Virginia.

In 1775 Washington, while on a visit here to locate lands granted him for his military services, set apart and deeded to the public forever a square acre of land on which was located a "burning spring." Through some informality his intention in this gift was frustrated.

In this same valley, in 1808, and soon after in the valley of the Muskingum, wells were drilled for brine and many primitive salt works were put in operation.

The method and tools for drilling wells evolved here were the progenitors of the method and tools now used in sinking oil and gas wells in similar formations all over the world.

The description[13] of an oil spring near Cuba, New York, made in 1833, says:

> Gas is constantly escaping through the water, and appears in bubbles upon its surface; it becomes much more abundant and rises in large volume whenever the mud at the bottom is stirred by a pole.

In 1833 Dr. Hildreth[14] gave a very entertaining description of the salt works of Ohio and West Virginia, and of the wells says: "All salt wells afford more or less of this interesting gas [natural gas], an agent intimately concerned in the free rise of the water, and universally present where salt water is found."

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[11] Henry's "Early and Later History of Petroleum."

[12] West Virginia Survey, vol. i (*a*), part i, page 2.

[13] Benjamin Silliman, Sr., vol. 23, p. 97, Jan., 1833, *Am. Journal of Science.*

[14] Dr. S. P. Hildreth, *Am. Journal of Science,* vol. 24, July, 1833, p. 46.

Fredonia, N. Y., has the distinction [15] of being the first place in America where natural gas was used for illumination. When this village was incorporated, its seal was designed to show a gas fixture.

In June, 1825, General Lafayette witnessed the illumination of this village with it after it had then been in domestic use some three or four years.

So far as has been ascertained, the first [16] use of natural gas in manufacturing in America was in "boiling salt" in the Kanawha Valley. Here, in 1841, William Tompkins, while boring for salt, struck a large and steady flow of gas, which was strong enough to force the salt water into a reservoir, from which it could be distributed to his furnace pans. He extemporized a gas holder from a hogshead placed over the salt water reservoir, into which he conveyed the escaping water and gas, the water falling into the reservoir, and the gas was conveyed through a pipe to the furnace and produced an intense heat under the whole row of kettles.

In 1843 a well near the Tompkins well, at a depth of 1,000 feet, threw a column of salt water and gas 150 feet high, and was the first "roarer" on record; and

> For many years [17] this natural flow of gas lifted the salt water 1,000 feet from the bottom of the well, forced it a mile or more through pipes to a salt furnace, raised it into a reservoir, boiled it in the furnace, and lighted the premises all around at night.

Knowledge of the existence [18] of oil and gas in the rocks of Ohio resulted largely from the search of the pioneers for that necessary article, common salt. Thus a well drilled in 1814, near the village of South Olive, Noble County, for brine, found such a pressure of gas that it threw salt water and some oil to a height of from 30 to 40 feet, and these eruptions continued for a period of 25 years. About the same time both oil and gas were discovered in Washington County. Similar results were secured at many points in the southeastern part of the State, but the oil and gas were regarded as a nuisance. The former ruined the brine for the manufacture of salt, and the latter was regarded as too dangerous for use.

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[15] Dr. Orton, p. 494, *Bulletin N. Y. State Museum,* vol. 6, No. 30.

[16] Eleventh Census, "History of the Use of Natural Gas in U. S.," p. 507.

[17] Quoted from West Virginia Geological Survey, vol. i, a, p. 11.

[18] Geological Survey of Ohio, fourth series, Bulletin 1, p. 31.

At Findlay, Ohio, natural gas was found in October, 1836, in digging a well. In 1838 gas from another water well was conducted by wooden tubes into a fireplace and burned from an old gun barrel. This continued in use for over forty years.

It is interesting to note that evidence of this kind led later to tests at several points, with the result that valuable pools of oil were discovered, and finally the great Trenton limestone field itself.

At Burksville,[19] Kentucky, in 1829, a well drilled for salt struck oil at 300 feet. The drilling tools were lifted out of the well by the force of the gas and a column of oil was thrown to the top of the trees.

About 1841, while some work for the removal of McGrew's Shoals, Tombigbee River, Alabama, was in progress, a well was drilled and oil struck at a depth of 365 feet, "which boiled[20] up very similar to the effervescence of a boiling pot."

Natural gas shows with salt water at the Central, Lower and Upper salt works and the sulphur springs at Jackson, all in Clark County, Alabama.

The Alabama geological[21] reports refer to the salt works, but do not mention the presence of natural gas.

I believe this showing of gas is a "marker" for a nearby oil and gas field in this formation. There has lately been natural gas developed in paying quantity in a lower formation in Fayette County.

The costal plains[22] of Louisiana and Texas contain a vast number of gas springs and a few showings of oil.

The settlers[23] in Texas as far back as 1820 knew of petroleum springs, "and they resorted to the places where it oozed from the ground as a black and pasty mass to gather it, though their only use for it was to grease the axles of their wagons, and to protect their implements from rust."

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[19] Sixteenth Annual Report U. S. Geol. Survey, part iv, p. 376.

[20] Said to be from Niles' National Register, Aug. 14, 1841.

[21] Report on the Geology of the Costal Plain of Alabama, by E. A. Smith.

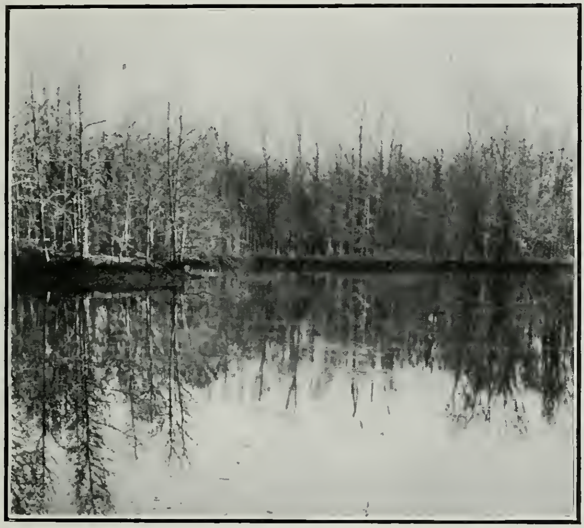
[22] Bulletins 184, 212 and 429, U. S. Geological Survey, treats largely of the Costal Plain.

[23] "Petroleum and Its Products," by Redwood, vol. i, p. 90.

A notable one of these places was at Sour Lake, Hardin County, where the occurrence of oil, asphalt, and gas had long been known.

Fig. 2 is a view of the Sour Lake; the spots of rippling water are caused by gas bubbling up, but this has now ceased, as the gas pressure has been reduced by drilling wells in the vicinity. The first attempts made in drilling here were failures, although promising indications were found.

FIG. 2.



Sour Lake, Texas.

After 1901, with increased drilling experience and better appliances, Sour Lake was developed as an oil field, and some 25,000,000 barrels of oil have been produced since.

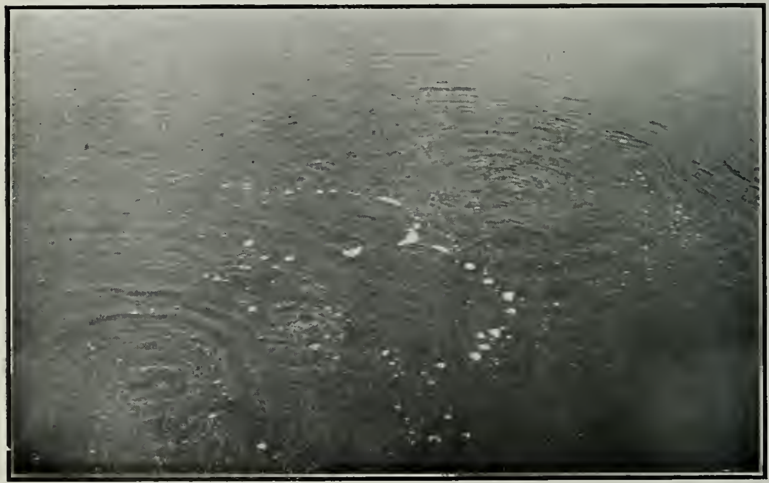
A small gas spring highly impregnated with sulphuretted hydrogen attracted attention to Spindle Top, a mound near Beaumont, Texas. Prior to 1899 several attempts were made to prospect this mound, but were failures for lack of experience and proper drilling machinery. In 1900 Captain A. F. Lucas drilled a well to prospect for sulphur to a depth of about 600 feet and got a good showing for oil.

A second well, with heavier rotary drilling machinery and more experienced drillers, got oil at between 1,100 and 1,200 feet and became the famous Lucas gusher.

The Spindle Top pool covered about 250 acres and has since yielded some 40,000,000 barrels of oil.

Attempts were made as early[24] as 1869 to drill for oil along the Gulf border, but oil in commercial quantity was not obtained until the Lucas gusher was developed in January, 1901.

FIG. 3.



Gas spring in Lake Felicity, La. This is typical of a large gas spring or escapement in water.

In 1903 I started out to look for oil indications along the Gulf border. I found true gas springs very abundant in Terrebonne Parish, Louisiana.

Fig. 3 shows a gas spring[25] in Lake Felicity, near its west shore. I should say that there was not less than 250 cubic feet of gas escaping per hour. This is typical of a large gas spring or escapement occurring in water.

The guide who showed me this place (Mr. Oscar Price) said that he had known of many of these escapements for over forty years, and they were much the same as to quantity of gas then as now, but that the vents changed somewhat in appearance from time to time, sometimes the gas escaping all at one place, and sometimes at several places, but not very far apart.

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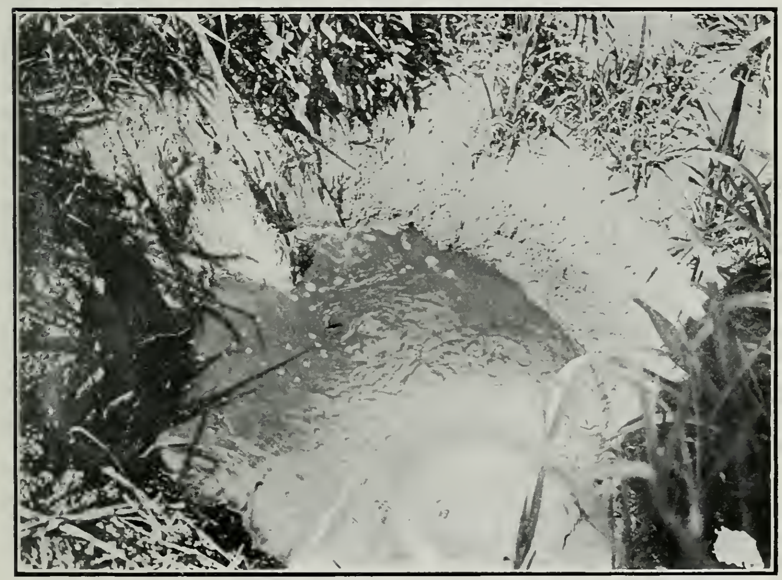
[24] Geological Survey of Louisiana, Report of 1899, p. 126.

[25] About in Sec. 25, Twp. 20, S. Range 19 East, Terrebonne Parish.

Fig. 4 shows a typical gas escapement in a field.

I am confident that such persistent gas springs as those mentioned, with hundreds of others of the same kind that occur in that vicinity, mean very extensive and productive oil-and-gas-bearing sands in Terrebonne Parish.

FIG. 4.



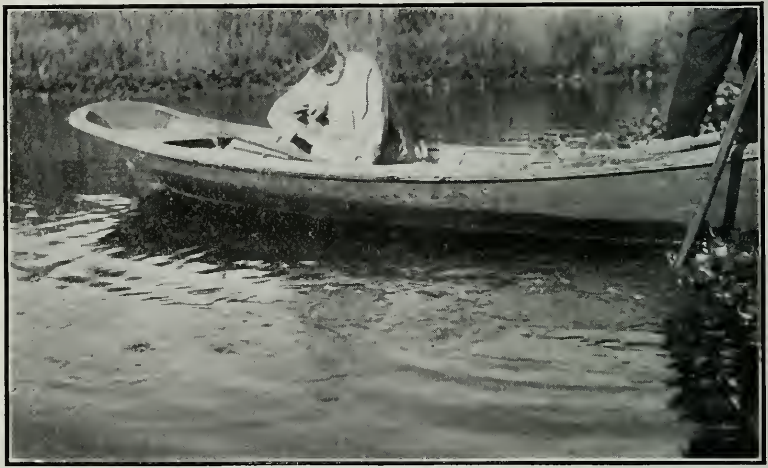
Blanchard's plantation, Bayou Terrebonne, La. Typical view of gas escapement in a field.

Abundance of gas can be obtained here, in places, by stirring up pools of water from the bottom, as shown by Fig. 5. I lighted this gas and the flame blistered the paint on the boat.

I visited this place several times and no gas could be seen unless the water was agitated or the bottom stirred. Such gas showings, I think, are due entirely to decaying vegetation near the surface, and are not fed from a deep source like the permanent gas springs mentioned.

The earliest settlers[26] of eastern Kansas learned from the Indians that "oil springs" existed in a number of places. Some were counted of wonderful efficacy by them, and the "medicine men" there obtained material to use in their various forms of "practice." These springs were principally in Miami and Wyandotte Counties. In Cherokee County, "Tar Creek" received its name from petroleum indications. I watched oil and gas developments in Kansas from 1895 and drilled over 200 wells. But one surface showing of oil came to my knowledge, and that was about six miles east of Chanute, where I saw a small showing of thick oil found by a farmer in digging for a cellar. People came to me many times to go and see gas springs. This occurred usually after a dry spell followed by a heavy rain, when the ground was filling up with water. Then crawfish holes in the bottoms, and mole and insect holes in the uplands, would, when conditions were right, show a bubbling that looked the same as gas, but would not flash or light.

FIG. 5.



Gas being stirred up by agitation.

In Oklahoma[27] burning springs are found in several parts of the State, the most notable being in northeastern Pittsburgh County, some twenty miles northeast of McAlester. At this point gas escapes over an area of perhaps 300 square feet. It issues from crevices in the soil and among the rocks, and when set on fire often continues burning for weeks.

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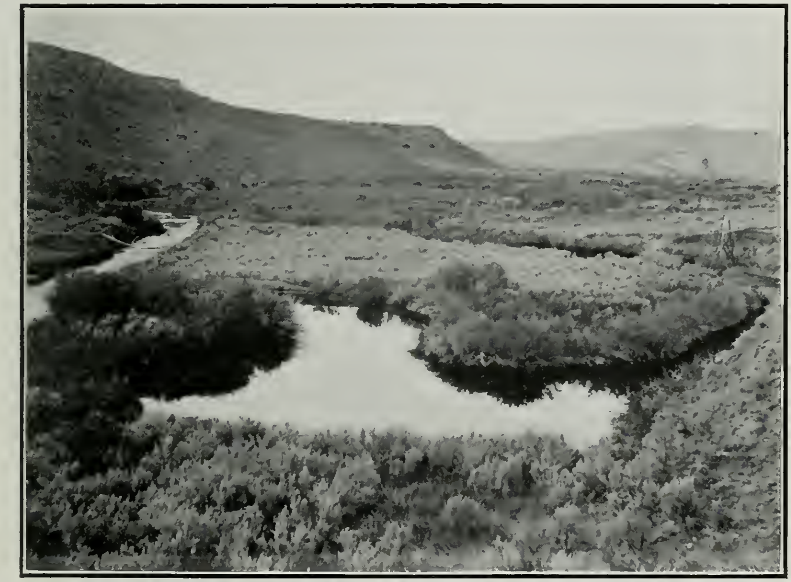
[26] Haworth in the University Geological Survey of Kansas, vol. i, p. 232. *Ibid.*, vol. ix, p. 25.

[27] Proceedings of the Natural Gas Association of America, vol. ii, p. 118.

In the summer of 1899 I visited the then territory of Wyoming[28] and saw many oil and gas springs. At Lander I met an old-time trapper who had lived among the Shoshones. He told me that the Indians knew of many oil and gas springs, and called them "the place of the Big Medicine."

FIG. 6.



View of the Little Pope Agie Valley, about ten miles southeast of Lander, Wyoming, in Twp. 32 N., R. 99 West.

Fig. 6 is a view of the Valley of the Little Popo Agie.[29] At the right is a derrick over the No. 1 Murphy Well, said to be 300 feet deep. At this place the oil and gas still seeped from the ground, as well as leaked from the well.

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[28] Sixteenth Annual Report, U. S. Geol. Survey, part iv, p. 382. Annual Report Territorial Geologist, 1886, Laramie, Wyo. Annual Report Territorial Geologist, 1888, Cheyenne, Wyo. Bulletin 119, U. S. Geol. Survey, p. 64. University of Wyoming Bulletin No. 14, Oct., 1893, p. 161. University of Wyoming Bulletin, No. 2, Petrol. Series, Jan., 1897.

[29] About 10 miles S. E. of Lander, in Twp. 32, N., R. 99 W.

About 1833 Captain Bonneville[30] "made search for the great tar springs, one of the wonders of the mountains, the medical properties of which he had heard extravagantly lauded by the trappers." His description points to this place, and when they found it "the men immediately hastened to collect a quantity of it to use as an ointment for the galled backs of their horses and as a balsam for their own pains and aches."

A cut-off had been dug across the original bend of the river, as seen to the left of the view, and dams put in, thus forming a U-shaped reservoir. I estimated that this contained 18,000 barrels of oil and was the accumulation of nine years' leakage around No. 1 well.

This oil made a great trap for ducks, geese, and other birds, for if they lit on its surface they could not rise again out of the thick oil; also, many sheep were lost in it. Before, and for a time after, the advent of the Union Pacific, oil from this place found profitable sale for lubricating purposes to the railroad, ranchers and mills, but eventually practically all this trade was lost through competition with Eastern refined oils.

An oil sand is shown cropping out in Fig. 7 above the man, and in front of him is a deposit made by oil seepage. At the foot of the slope was a strong gas escapement.[31]

In the early days of California[32] the Catholic fathers utilized asphaltum for roofing their missions and other buildings from nearby deposits, and from time immemorial the Indians had known of and used this mineral.

The first discovery of bitumen at Summerland,[33] California, was where there was a fumarole, some twenty feet in diameter, from which warm carburetted and sulphuretted hydrogen gas escaped. No vegetation grew on this place. The Spaniards had a legend that a man was killed there, which, according to them, accounted for the fact that nothing grew there.

A pipe driven in this spring and reduced to two inches gave pressure and quantity enough of gas to make a flame ten feet long. The following up of this discovery led to drilling submarine oil wells from a wharf. Cooper says:[34] "Frequently gases are seen to ascend from the bottom of streams and pools of water, and that it occurs in many places in California."

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[30] Washington Irving's "Bonneville," p. 142.

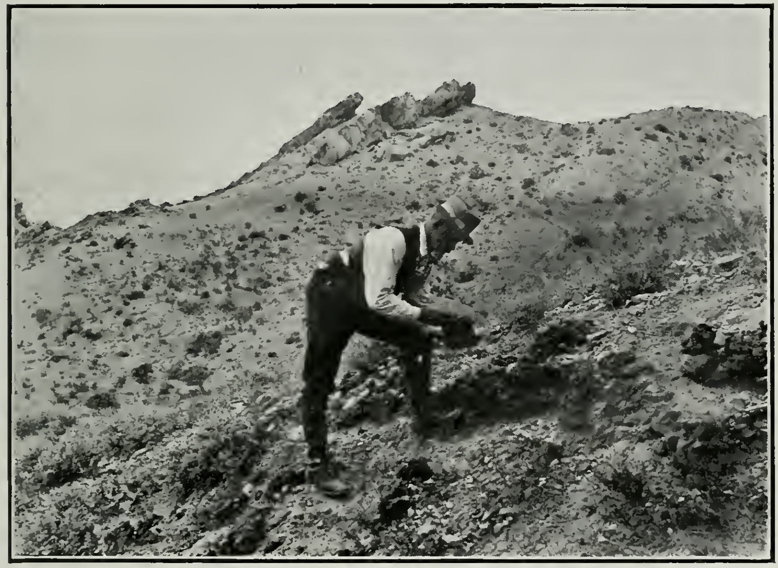
[31] In Fremont County, Wyoming, about forty miles due east of Lander.

[32] "Petroleum in California," by Redpath.

[33] Bulletin No. 16, State Mining Bureau, 1899, p. 62.

I have shown a wide geographic distribution of bitumen, and particularly of natural gas. It is one of the most difficult facts of history to understand the extreme slowness with which the human race developed the industrial use of bitumens, especially that of oil and gas. It is only about thirty years since natural gas began to come in use on a large commercial scale.

FIG. 7.



Fremont County, Wyoming, about 40 miles due east of Lander. Oil sand croppings and hardened oil made by seepage.

Time forbids that I should dwell longer on the history and surface indications of bitumens, so I will pass to the next part of my subject.

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[34] Bulletin No. 16, State Mining Bureau, 1899, p. 83. See Bulletin No. 321, U. S. Geol. Survey, part i, p. 11 and quotation bottom page 13.

SECTION II.

ORIGIN OF BITUMENS.

Many theories have been put forward to account for the origin of bitumens in the crust of the earth. There are two main groups of these hypotheses, one ascribing an inorganic and the other an organic origin.

The celebrated chemists [35] Bertholet and Mendeljiff pointed out (in 1869 and 1877) possible chemical reactions under which hydrocarbon compounds could be generated in the earth's interior. Some advocate a volcanic origin [36] of natural gas and petroleum, and give examples of hydrocarbons in ancient plutonic rocks as well as in present volcanoes.

The organic [37] hypothesis can be backed by more familiar facts than those just outlined.

Natural gas and other bitumens are combustible substances, and every other substance that we know in Nature that can be burned is organic in origin.

Chemists have produced unmistakable members of the petroleum group, including illuminating oil, lubricating oil, benzine, and paraffin, from the distillation of fish oil, and in such distillations some gas is given off.

By observation [38] we know that natural or marsh gas is a product of slow primary decomposition at low temperature of organic matter contained in sediments, and so is from an organic source. These decompositions were extremely slow, and the present pools of oil and gas are the accumulation of enormously long periods of time.

I think it is safe to say, from our present knowledge, that some bitumens may come from an inorganic source, but by far the greater amount come from terrestrial and marine vegetation and organisms.

We might well adopt for our conclusions the translation of an inscription placed over a meteorite that fell centuries ago in Germany: "Many men say many things; every one says something; nobody gives a satisfactory account."

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[35] Tenth Census, vol. x, p. 59.

[36] *Journal Can. Min. Inst.*, vol. iii, pp. 68-89.

[37] Adapted from Dr. Orton, *Bulletin N. Y. State Museum*, vol. 6, No. 30, p. 426.

[38] U. S. Geol. Survey, Eleventh Ann. Rep., part 1, p. 613.

SECTION III.

THE GEOLOGY OF BITUMEN.

With Especial Reference to Natural Gas.

In the gaseous, liquid, and solid forms bitumen is one of the most widely distributed of substances. Its geological limits of profitable production include the whole range of unaltered strata, from the Cambrian rocks to the most recent series of the Quarternary system.

The publications of the United States Geological Survey, with those of the several States, and of the geological societies, give a wealth of detail of the geology of every locality in the United States where oil and gas are now produced in paying quantity. These works should be consulted on geological questions. Many of them can be had for the asking, and for those that are sold the price only covers the cost of printing and mailing.

Geology is more of a historic than exact science, with but few demonstrations of the sort that carry mathematical certainty, and the wise geologist confines his teachings to the known, without attempting the rôle of a prophet.

The principles[39] of geology are not visionary; they are supported by a great multitude of harmonized facts. The maps and sections in the publications mentioned show this to be the case. But the geologist does not know whether a sand[40] exists at a given spot beneath the surface, nor whether, if there be a sand, it holds gas or not, nor whether, if the gas be there, it will flow toward a drill hole. But this ignorance of facts, all of them out of sight and out of reach before experiment, he shares with everybody else. No one, absolutely no one, can know such facts before a well is bored.

Rocks are of many kinds, and as the paying pools of gas are found only in those of sedimentary origin, I will refer to this kind only.

Such rocks are composed of the detritus of older rocks and carried by water, air, and ice in motion into lakes and seas, forming gravels, sands, and clays which are later consolidated into conglomerates, sandstones, and shales.

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[39] Adapted from J. P. Lesley's letter of transmission, Penna., Second Geological Survey, vol. iii.

[40] Sand is a general term, and includes sandstone and limestones that carry oil or gas in paying quantity.

In smaller portion the materials are also carried in solution, and the deposits are then called organic, if formed with the aid of life, and chemical without this aid. Organic and chemical rocks are limestones, cherts, gypsums, peat, lignite, and coal.

Much terrestrial and marine vegetation with marine, brackish, or fresh-water organisms is thrown down with such deposits, forming, in the aggregate, a vast amount of carbonaceous material sufficient to account for all the gas and other bitumens found in Nature.

These sedimentary rocks are mostly deposited in layers or beds originally in a horizontal position, or nearly so, and which can easily be separated. These layers are called strata, and the deposits are said to be stratified.

Most of such rocks grew up in the sea, some cover thousands of square miles, and for the accumulation and growth of these enormous deposits vast periods of time were required.

All stratified rocks can be divided into two general divisions with reference to their porosity—the permeable and the impermeable. Some rocks are freely permeable, others are less so, and still others resist the passage of water so effectually that we call them impermeable.

Conglomerates and sandstones are types of the porous group. Shales and clays represent the impervious series, and are perfect seals when they carry moisture.

Dolomitic and crinoidal limestones, under certain conditions, are also porous, but most of the limestones are impervious.

The porous rocks usually contain water, and when near the surface it is fresh. Sometimes they are dry, or they contain gas only, or they contain oil and gas, or they contain oil, gas, and water, and such rocks are referred to as reservoir rocks, and I will describe them more particularly later.

When water is associated with oil or gas or nearby strata below or above them, it is invariably impregnated with salt or sulphur, or both. Outside of oil and gas territory, potable water may be got at considerable depth, as at Charleston, S. C., where warm potable water (99½° F.) is obtained between 1,950 and 2,000 feet.

Porous rocks, which have become a reservoir particularly of oil or gas, have so become by virtue of the fact that its contents are confined within it by an impervious covering which generally consists of shale or clay carrying some moisture.

By orogenic movements the stratified rocks have been arched up, thrown into waves and crumpled. The crystallization of salt [41] from solution and intrusion of laccoliths has in a few places raised up dome-shaped hills of these rocks, and volcanic plugs and vents have been forced up through them. Such disturbances of original structure have formed anticlinals, synclinals, domes, fault, joint cracks, and volcanic vents, and these variations play an important part in the accumulation and concentration of oil and gas into paying "fields" or "pools."

The fundamental geologic conditions necessary for a profitable accumulation of oil or gas must be:

First. A source of supply, probably from carbonaceous material enclosed in sedimentary strata.

Second. A reservoir rock such as may be found in any porous rock that will allow the passage of fluids between its particles.

Third. A cover of impervious moisture holding rocks to seal and hold the oil and gas from loss by dissipation.

SECTION IV.

CLASSIFICATION OF OIL AND GAS ACCUMULATIONS.[42]

I. Where anticlinal and synclinal structure exists.
   (*a*) Strong anticlines standing alone.
   (*b*) Well-defined anticlines and synclines alternating.
   (*c*) Monoclinal dips.
   (*d*) Terrace structures.
   (*e*) Broad geanticlinal folds.
   (*f*) Overturned folds.

II. Without anticlinal structure.
   (*a*) Lenticular sandstones enclosed in shale.

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[41] G. D. Harris in Bulletin No. 429, U. S. Geological Survey, p. 8.
[42] "Economic Geology," by F. G. Clapp, vol. v, No. 6, pp. 503–521.

(*b*) Sandstones that shade into shale.

Both (*a*) and (*b*) are entirely enclosed in shale and not in communication with water under hydrostatic pressure.

III. Domes, or quaquaversal structures.
IV. Sealed faults.
V. Oil and gas sealed in by asphaltic deposits.
VI. Contact of sedimentary and crystalline rocks.
VII. Joint cracks.
VIII. Surrounding volcanic vents.

The great gas fields come under the first two classes of accumulations, and as the gas associated with the other classes is not of commercial importance I will not refer further to them.

Through the investigations of geologists [43] working in the great Appalachian field the structural or anticlinal theory of the accumulation of oil and gas was evolved.

The three fundamental geologic conditions for the accumulation of oil and gas have been previously stated. In addition to these, for the proper theoretical anticlinal conditions we should have:

Fourth. Water in the porous stratum with the oil and gas.

Fifth. Geologic structure, or a decided slope of the porous stratum.

It cannot be doubted that the fifth condition mentioned,—geologic structure—does play an important part in the accumulation of oil, and particularly of gas, and it is a fact that many gas pools are located along anticlinals and in domes, but the theory is not, in my opinion, of universal application.

To such fields as the theory applies [44] it is of economic importance, and the geologist should be consulted to locate favorable points in advance of any drilling.

Fig. 8 is a well section across the oil and gas trend just east of Chanute, Kansas. The productive oil sand shown at this point is about one-third of a mile wide and 20 to 30 feet

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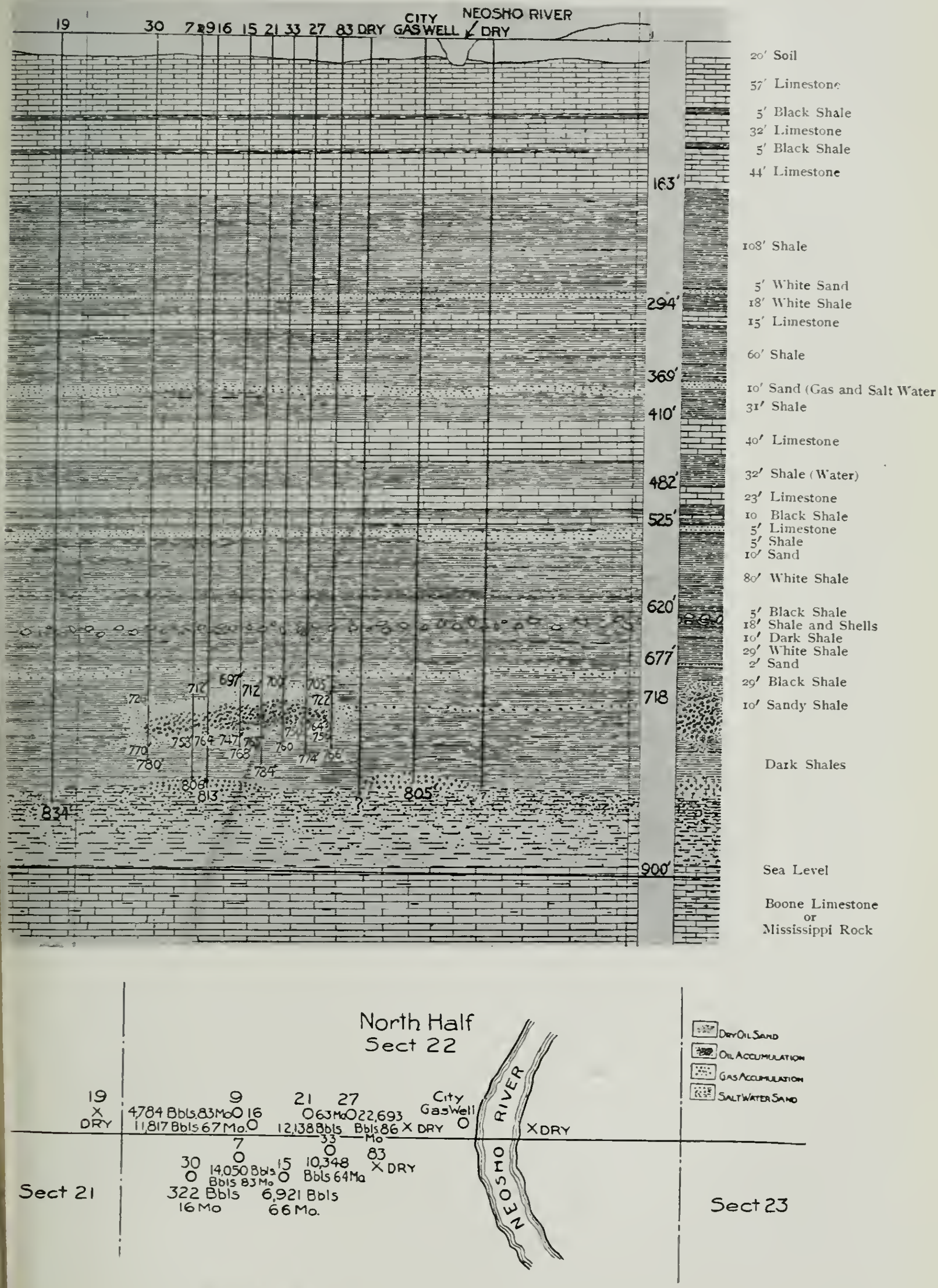
[43] See "History of the Structural or Anticlinal Theory," by I. C. White, West Virginia Geol. Survey, vol. i (a), 1904, p. 48.

[44] West Virginia Geol. Survey, vol. i, p. 60.

Fig. 8.

Plan and section of wells drilled by I. N. Knapp, one mile east of Chanute, Kansas, showing average width of productive oil sand from east to west, total length about three miles north and south. Small spots of gas sand under soil.



thick. The real productive sand is from 10 to 15 feet thick and 700 to 750 feet deep in the level lands along the Neosho River. It varies in width from one-fourth to one-half a mile, and is about five miles long, along the strike of the dip, and practically exactly horizontal in width and length. It is, therefore, not a continuous sheet of sandstone like the Pennsylvania oil sands or Trenton rock. It carries nothing but oil, and does not connect at any place with water-bearing strata, but grades into impervious shales in all directions. The oil is combined with but little gas, and wells will not flow unless drilled deep enough to prick the gas sand if found below.

It is evident that the anticlinal theory played no part in the accumulation of oil in this particular sand.

Below the oil horizon, some thirty to forty feet, and just on top of the salt-water sand, is a gas horizon with occasional spots productive of gas. The southernmost well that I drilled in this trend proved to be a gasser at 781 feet, and the northernmost well, three miles away, a gasser at 780 feet, the tops of the wells being probably within five feet of the same elevation. The gas sands here appear like small sand bars or sand dunes laid down on top of the salt-water sand, which were covered up by mud (the shales) and in time cemented into the rock we find. The gas sand (cuttings from the gas-bearing sandstone) and the salt-water sand (cuttings from the salt-water sand rock) are quite different in appearance. The salt-water sand carries minute particles of mica that are characteristic, and as soon as they appear in the cuttings, even before salt water shows, it is at once recognized that no gas will be obtained at that particular point.

At Altoona, Kansas, my drilling developed gas in two sands having the same relative position as the oil and gas sand at Chanute.

The conclusion is that each oil and gas field must be considered by itself, both from a geologic and operating standpoint. The geologist, operator, or driller expert in one field has to learn the business over again when he goes into a new field.

When a man starts as pioneer in a new field in which practically nothing is known of its geology, with no well records or methods of operating work out, he is up against a pretty hard proposition.

SECTION V.

RESERVOIR ROCKS.

The porosity of rocks,[45] sand, and earth has been the subject of elaborate investigation as to their capacity to hold water, and the rate of flow of water and air through them. It has been shown that if a theoretical sand consisted of perfect spheres of equal diameter, placed at a maximum distance apart, the pore space is 47.64 per cent.; if at a minimum, 25.95 per cent. These percentages hold true, no matter what the diameter is. This proves the pore space is the same in a fine sand as in a coarse one.

If a quantity of common shot be poured in a glass and the open spaces filled with water, the porosity will be found well within the limits given, whether the shot be fine or coarse, and the same is true of common sand.

After the sands of the sandstones were laid down they have been subject to "secondary growth" by the slow deposition of cementing material from circulation of underground waters, thus forming rock and reducing the original porosity in varying degree. The porosity of limestones has also been decreased in similar ways and also increased by solution.

The fractional part of a rock in which there are open spaces or voids determines its porosity. That is, if a cubic foot of rock will hold, when saturated, one-tenth of a cubic foot of oil or water, such rock is said to have a porosity of 10 per cent., for one-tenth of its volume is pore space. If such pore space was filled with gas at 30 atmospheres, then each cubic foot of rock would hold 3 cubic feet of gas at atmospheric pressure.

All rocks are porous in some degree. Even slate of the closest grain will hold some liquid in its microscopic cavities. Those rocks that are so open-grained or porous that, if a hole be drilled into them, they can be drained of their liquid or gaseous contents are called reservoir rocks.

The porosity of the reservoir rocks often extends to great distances. Striking proof of this is supplied in the practical development of many gas fields. In northwestern Ohio,[46] according to Dr. Orton, wells separated by intervals of a half or three-quarters of a mile are found to affect each other's flow and pressure to an important degree, and it is also found that areas of several consecutive square miles can sometimes be drained of their gas by a single well.

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[45] See papers of F. H. King and C. S. Slichter, Nineteenth Annual Report, Geol. Survey, part ii, 1897–1898.

[46] Geological Survey of Ohio, 1890, p. 88.

Underground[47] water may be found in cracks and crevices in rocks, but by far the larger portion exists in the minute pores and openings between the rock particles themselves.

Caves, cracks, or crevices in rock are largely surface phenomena. Below the surface, as the depth increases, the weight of the superincumbent material tends to close any opening, and Professor Van Hise[48] shows that at a depth of about six miles the weight is so great that all rocks become plastic and flow so as to close up even their minute microscopic pores.

A West Virginia well[49] developed gas in the Gantz sand horizon at 2,770 feet, as well as in the "Fifty-foot" sand at 2,840 feet, and a still larger flow was found in the fifth or McDonald sand at 3,115 feet, the hole being completed at 3,300 feet. The Gantz and "Fifty-foot" sands constituted one solid, coarse, pebbly rock, and in order to save all of the gas flows the well was packed in the upper portion of this pebbly stratum. From the great depth of the well it was expected that the rock pressure would rise until it exceeded 1,500 pounds to the square inch, but when shut in the gauge, which began to register rapidly at first, very soon slowed up, and finally stopped at 650 pounds. As the pressure did not rise sufficiently rapid to correspond to the apparent volume of the gas when the gate valve was open, it was concluded that a large portion of the gas was being forced into the porous Gantz and "Fifty-foot" beds and stored therein, the 650 pounds representing the pressure necessary to store in the pores of that rock all the surplus gas produced from the three horizons at that pressure.

(*To be continued.*)

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[47] See U. S. Geological Survey Water Supply and Irrig., Paper No. 67, pp. 14–16.

[48] See paper of C. R. Van Hise, Sixteenth Annual Report, U. S. Geol. Survey, part i, 1896, p. 593.

[49] West Va. Geol. Survey, vol. i (a), p. 7. Alonzo Edwards Well No. 1, near Wadestown, Monongalia Co., W. Va.

THE ELECTRO-PNEUMATIC BRAKE SYSTEM FOR STEAM ROAD SERVICE.[1]

BY

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The air-brake equipment for steam road cars hereinafter described is the outcome of a close acquaintance with and a careful study of the present-day requirements of steam road service, which brings a realization of the present limitations of the air-brake equipment.

There has been such marked improvement in the design and construction of railway motive power and rolling stock during late years that the best possible air-brake equipment should be considered none too good.

The demonstration train (Fig. 28) which the Santa Fe Railroad Company hauled over its lines some months ago for educative purposes clearly illustrates this wonderful advancement.

The train was composed of two locomotives, and two each of the various types of cars for both freight and passenger service, one of each being built in 1881, and the other in 1911. The locomotive, no doubt, shows the most wonderful development. The No. 0–48, built in 1881, weighs 133,000 pounds and has a drawbar pull of 14,000 pounds, as against 850,000 pounds weight and a drawbar pull of 110,000 pounds for locomotive No. 3009, built in 1911. This large locomotive is able to draw much heavier and longer trains, and consequently the time element in the application of the brakes between the first car and the last will be increased accordingly, with a corresponding increase in the possibilities of damage, due to slack running in or out. The smokers and coaches also show a great increase in size and capacity, the older smoker having a weight of 49,400 pounds and a capacity of 28 passengers as against 119,100 pounds weight and 86 passengers with the latest type. The coach of 1881 has a weight of 50,300 pounds with a capacity of 48 passengers, while the modern coach seats 75 passengers and weighs 123,100 pounds.

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[1] Concluded from page 464.

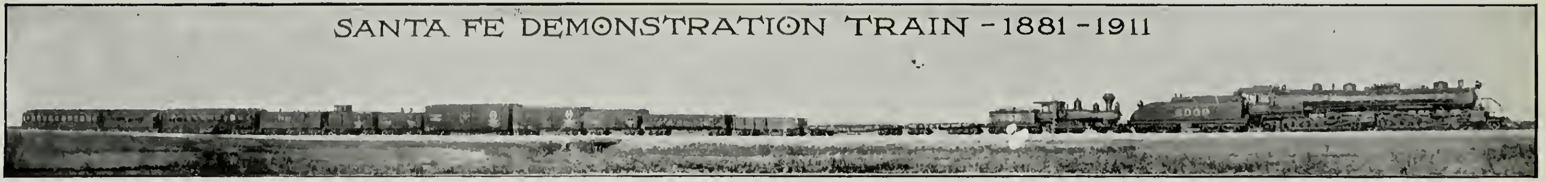
Natural improvement, combined with the effort of railroad companies to attract business by superior equipment, and the demand of the travelling public for greater comfort when travelling, shorter schedules (higher speeds), and, at the same time, greater safety, has led to the development of heavier rolling stock. These cars and locomotives are of such weight that they cannot be as efficiently braked with the older type of air-brake equipment as could the rolling stock of years gone by; and this is particularly true of emergency applications, as because of the very high speeds attained and the large cylinders necessarily employed the time element in the attainment of cylinder pressure, and the lowered brake-shoe friction (by reason of the tremendous energy per brake shoe to be dissipated), means that the stopping distance, with the brake equipment remaining the same as with the rolling stock of previous years, is lengthened out several hundred feet. Obviously, therefore, if equal safety is to be maintained and the schedules operated profitably, at least as high (relative) a rate of retardation must be provided as heretofore.

It has already been pointed out that actuating the brakes electrically results merely in the elimination of the time element of application, the retarding force coming solely from the pneumatic operation, and that adding electric control without first developing the pneumatic features to a high degree is an expensive way of seeking improvement.

Not only this, but the heavier vehicles and lengthened trains have vastly increased the energy to be controlled and magnified the time element necessarily involved in so doing it. It is imperative that if the same relative freedom from surges, shocks, and stresses is to be retained, the brake control must be much more flexible and responsive than has heretofore been the case.

With this end in view, great improvements have been made in the purely pneumatic brake, but full attainment is only possible when the pneumatic brake is operated electrically, as by

Fig. 28.



RELATIVE WEIGHT

	OLD EQUIPMENT	NEW EQUIPMENT
Locomotive	133,000 pounds	850,000 pounds
Flat car	10,200 pounds	32,100 pounds
Coal car	22,000 pounds	30,500 pounds
Stock car	20,000 pounds	45,200 pounds
Box car	22,000 pounds	40,000 pounds
Way car	23,800 pounds	38,000 pounds
Smoker	40,400 pounds	110,100 pounds
Coach	50,300 pounds	123,100 pounds

RELATIVE CAPACITY

	OLD EQUIPMENT.	NEW EQUIPMENT.
Locomotive	14,000 pounds drawbar pull	110,000 pounds drawbar pull
Flat car	40,000 pounds	80,000 pounds
Coal car	50,000 pounds	80,000 pounds
Stock car	40,000 pounds	80,000 pounds
Box car	40,000 pounds	80,000 pounds
Smoker	28 passengers	86 passengers
Coach	48 passengers	75 passengers

RELATIVE COST

	OLD EQUIPMENT	NEW EQUIPMENT
Locomotive	$7,740.00	$43,880.00
Flat car	300.00	943.00
Coal car	338.00	1,030.00
Stock car	460.00	1,402.00
Box car	475.00	1,265.00
Way car	620.00	1,282.00
Smoker	3,000.00	12,124.00
Coach	3,005.00	12,820.00

ENGINE 3009

Santa Fe Type Mallet Compound.
Largest Locomotive in the World.
Built at Topeka Shops, 1911.
Length 120 feet 7¾ inches
Cylinders 26 In x 38 In x 32 In stroke.
Steam pressure 225 pounds.
Capacity of tender 12,000 Gals. Water,
4,000 Gals Fuel Oil.

OLDEST TRAIN CREW

E B Sill, Conductor, 33 Years' Service
Peter Tellin, Engineer, 39 Years' Service.

this means the time element between the first and rear of train is reduced, and the degree of retardation best suited to speed can be measured to a degree.

As intimated in the commencement of the paper, this has long been known, for it is obvious that with any class of rolling stock or make-up of train the elimination of the time element of brake operation will be both an improvement in this respect and also in the degree of perfection required in the human agents in its manipulation.

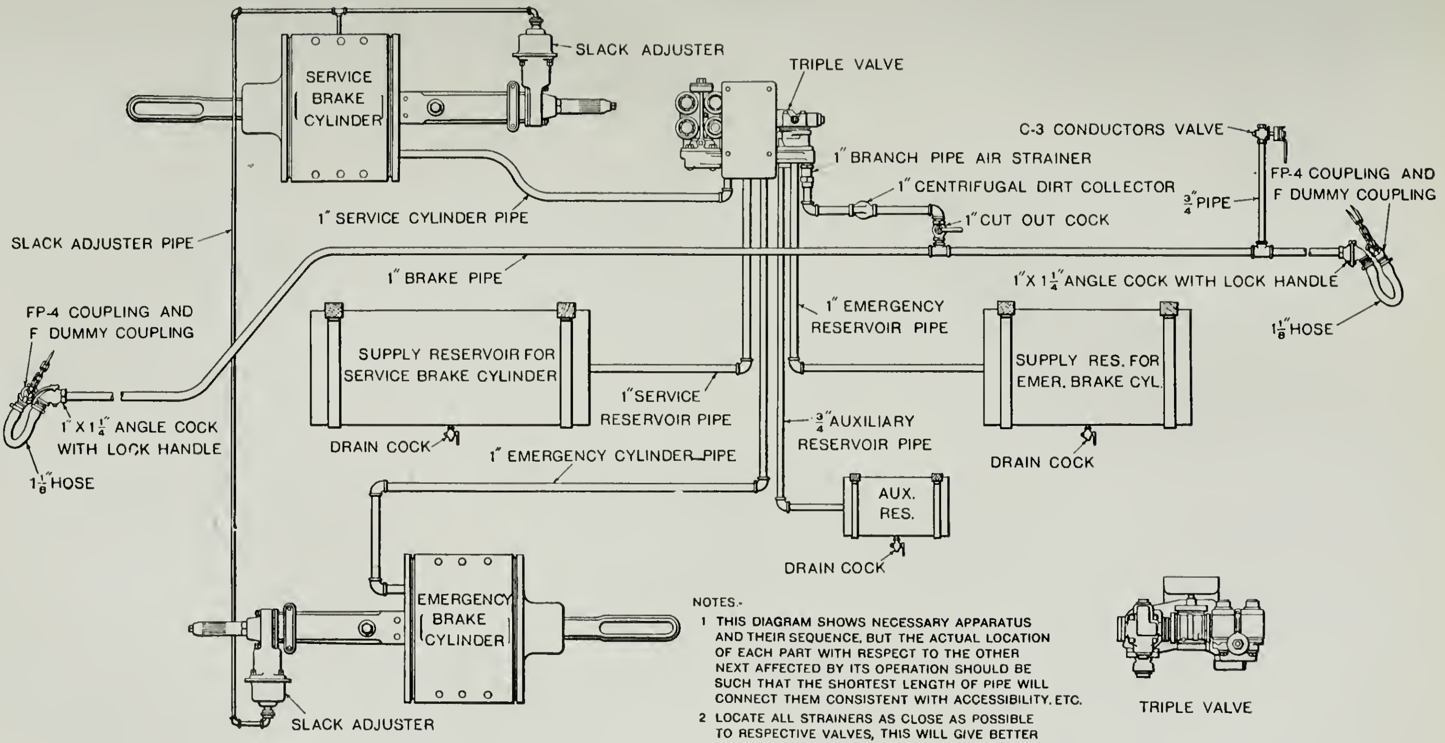
Coincident, however, with the other advancements, electric lighting of trains coming into existence, and its almost universal use on trains of such car equipment, has given an opportunity of an electric pneumatic system of brakes for the control of even " steam road " trains.

Therefore the pneumatic brake portion of the equipment hereinafter described is of the highest type yet designed for steam road service, and has electric control for both service and emergency operations. It has all the important features necessary for a very efficient pneumatic brake, as enumerated in connection with the previously-described equipment, with the addition of others which are necessary in order that the heavy trains in steam road service may be braked, conformable to reasonable requirements.

Two brake cylinders are used, one for service application and both for emergency. A low total leverage is possible (resulting in greatly-increased overall efficiency and economy of locomotive power) since the braking power is based on an equalization pressure of 86 pounds instead of 50 pounds as with former equipments.

Fig. 29 shows the piping diagram of this equipment, which pneumatically consists of a control valve; auxiliary, service and emergency reservoirs; and service and emergency brake cylinders. The auxiliary and service reservoirs combined form the reservoir volume for the service brake cylinder, and are so connected that when recharging the equipment (graduated release feature cut out), after a brake application, the service reservoir is temporarily cut off from the source of air supply and only the small auxiliary reservoir volume is added to the brake pipe, which reduces to a minimum the amount of air required to release all the brakes in the train. After the brake-

FIG. 29.


SLACK ADJUSTER
SERVICE BRAKE CYLINDER
TRIPLE VALVE
C-3 CONDUCTORS VALVE
1" BRANCH PIPE AIR STRAINER
FP-4 COUPLING AND F DUMMY COUPLING
1" CENTRIFUGAL DIRT COLLECTOR
3/4" PIPE
1" CUT OUT COCK
1" SERVICE CYLINDER PIPE
SLACK ADJUSTER PIPE
1" BRAKE PIPE
1" X 1 1/4" ANGLE COCK WITH LOCK HANDLE
FP-4 COUPLING AND F DUMMY COUPLING
1" EMERGENCY RESERVOIR PIPE
1 1/8" HOSE
SUPPLY RESERVOIR FOR SERVICE BRAKE CYLINDER
SUPPLY RES. FOR EMER. BRAKE CYL.
1" SERVICE RESERVOIR PIPE
1" X 1 1/4" ANGLE COCK WITH LOCK HANDLE
3/4" AUXILIARY RESERVOIR PIPE
DRAIN COCK
1" EMERGENCY CYLINDER PIPE
DRAIN COCK
1 1/8" HOSE
AUX. RES.
DRAIN COCK
EMERGENCY BRAKE CYLINDER
SLACK ADJUSTER
TRIPLE VALVE

NOTES.-

1 THIS DIAGRAM SHOWS NECESSARY APPARATUS AND THEIR SEQUENCE, BUT THE ACTUAL LOCATION OF EACH PART WITH RESPECT TO THE OTHER NEXT AFFECTED BY ITS OPERATION SHOULD BE SUCH THAT THE SHORTEST LENGTH OF PIPE WILL CONNECT THEM CONSISTENT WITH ACCESSIBILITY, ETC.

2 LOCATE ALL STRAINERS AS CLOSE AS POSSIBLE TO RESPECTIVE VALVES, THIS WILL GIVE BETTER PROTECTION TO THE VALVES.

3 POSITION OF CUT OUT COCKS SHOULD BE SUCH AS TO PREVENT HANDLE BEING JARRED INTO A CLOSED POSITION WHEN IT SHOULD BE OPEN OR JARRED OPEN WHEN IT SHOULD BE CLOSED

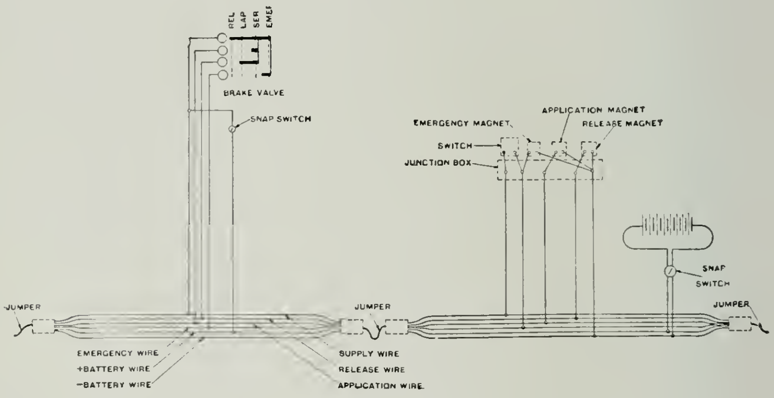
4 DIRT COLLECTOR TO BE LOCATED WITHIN 24" OF TRIPLE VALVE.

Piping Diagram.

pipe and auxiliary reservoir pressure has increased to within five pounds of the maximum pressure carried in the system or within five pounds of the pressure in the emergency reservoir, the service reservoir is automatically cut in and will then charge to the same pressure as that to which the system is limited.

The dividing of the auxiliary reservoir volume into two volumes permits of a very flexible graduated release with a minimum emergency reservoir volume, as the graduated release feature is controlled by the emergency reservoir air expanding into the auxiliary reservoir volume; also to have a smaller volume for the emergency reservoir to equalize with in graduated release operation, thereby making this feature more positive than heretofore, as with the older types of brake.

Fig. 30.

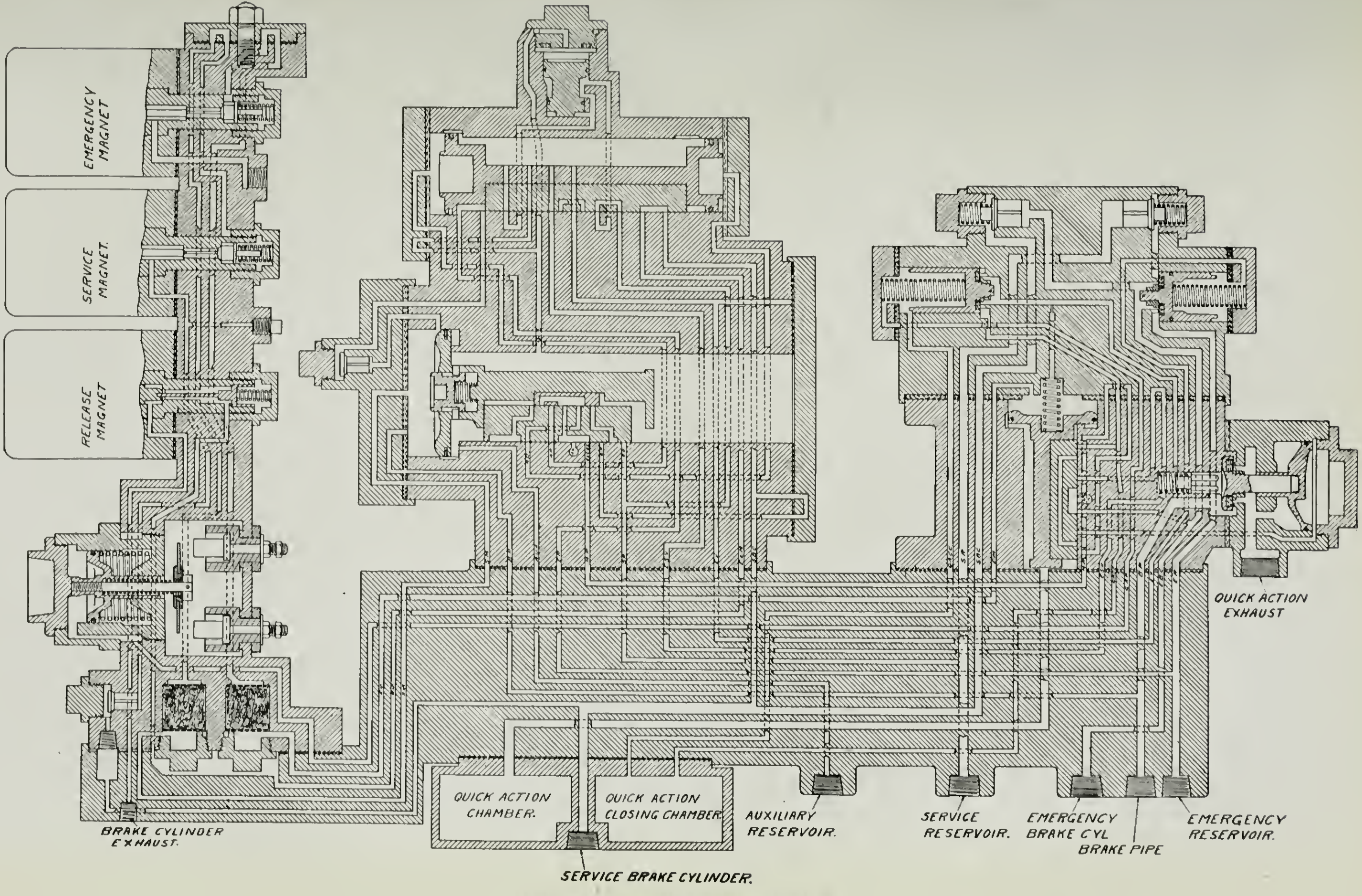


Wiring Diagram.

The emergency reservoir, besides being used in obtaining the graduated release, equalizes with the emergency brake cylinder in an emergency application of the brake.

Fig. 30 shows the wiring diagram. Electrically the equipment comprises the usual application and release magnets, with their attached valves controlling electric service application and release of the brakes, and also the emergency application magnet with its valve, which controls the operation of the emergency parts of the control valve. The emergency switch is used to close the emergency magnet circuit and thus cause the electro-pneumatic emergency, whenever there is a very sudden reduction

Fig. 31.



Control Valve, Diagrammatic Assembly

in brake-pipe pressure, such as when a hose bursts or separates.

Fig. 31 shows the control valve, which is comprised of three general portions, viz., equalizing, magnet, and emergency portions, and a three-faced pipe bracket for these portions, as shown on the diagrammatic drawing.

The *equalizing portion* (central part of figure) is similar to a plain triple valve and controls the application of the service brake and, by means of the release piston and valve, the graduated release and the release of the service cylinder pressure.

The *magnet portion* (left-hand part of figure) is composed of three magnets and their valves and also the emergency switch. These magnets are the service, emergency, and release magnets, and control the electro-pneumatic operations which their names imply. The emergency switch is used to close the emergency magnet line circuit and thus cause electro-pneumatic emergency whenever there is a very sudden reduction in brake-pipe pressure, such as when a hose bursts or separates.

The *emergency portion* (right-hand part of figure) controls the pneumatic emergency, the connecting of the emergency reservoir and cylinder, and also embodies the protection valve, which causes quick action whenever the brake-pipe reduction is carried below a certain predetermined point; the two check valves which allow the two reservoirs and cylinders to finally equalize in an emergency application are also located in this portion.

OPERATION OF THE ELECTRO-PNEUMATIC CONTROL VALVE FOR STEAM ROAD SERVICE.

Charging the System.

Air from the brake-pipe enters the control valve at connection marked " Brake Pipe " and flows to the under side of the quick-action valve, forcing same to its seat, also to the under side of the protection valve, which remains seated until a certain predetermined pressure is obtained, when it will move very quickly and seat toward the left, owing to its left side being connected to the quick-action closing chamber, which, under these conditions, is open to the atmosphere by means of the quick-action piston and emergency switch port.

Brake-pipe air flowing to the under side of the protection valve can also flow through the small choke into the emergency slide-valve piston cylinder, and force same to the release position: this air can flow through the emergency piston feed groove and charge the quick-action chamber.

With the emergency slide valve in release position, the emergency brake cylinder is open to the atmosphere, through the exhaust cavity in the face of this valve.

After the protection valve lifts and separates the quick-action closing chamber vent and quick-action piston ports, the brake-pipe air can flow through the quick-action closing chamber charging port, charging this chamber at the same time as the brake pipe.

Brake-pipe air can also flow to the face of equalizing piston, forcing same to its release position, and charging through the feed groove into the equalizing slide-valve chamber and the auxiliary reservoir.

Air in the equalizing piston cylinder can also raise the emergency reservoir charging check valve, and flow past same to the release slide-valve chamber and thence to the emergency reservoir, and since this and the equalizing slide-valve chambers are connected, the auxiliary and emergency reservoirs will charge at one and the same time from zero pounds pressure. The equalizing slide-valve chamber is also connected to the top of the charging valve, forcing it downward against its stop, and thus opening the service reservoir charging port, which leads through the release slide valve and piston to the under side, as well as the side of the charging valve, to the service reservoir port—the latter port passing through and being controlled by the release slide valve. In this position the small end of the release piston is open to the atmosphere through the equalizing slide and graduating valves, consequently the release piston will be held in release position.

The release slide-valve chamber is open through the emergency valve port to the top of the emergency valve, and the emergency reservoir air is in communication with its under side, hence this valve is balanced and is held seated by its spring. Emergency reservoir air is also present on top of the emergency reservoir check valve and the service reservoir air is in communication with its under side: this valve permits these two volumes to be connected in an emergency application.

With the release slide valve in release position, the service brake cylinder is open to the atmosphere through the release slide-valve cavity and the release magnet.

Brake-pipe air entering the equalizing piston cylinder will also flow through the service magnet port and strainer to the top of the service magnet valve; and the brake-pipe air in the emergency piston cylinder will also flow through the emergency magnet port and strainer to the top of the emergency magnet valve.

In release position the tops of the emergency switch, protection valve, and quick-action piston are connected to the atmosphere by means of a small drilled hole in the latter and the quick-action exhaust.

ELECTRIC SERVICE APPLICATION.

When an electric service application of the brakes is desired, the brake-valve handle is moved to the service application position, which is the same for both electric and pneumatic operation, in which the release magnet circuit is closed, energizing this magnet, which in turn seats its valve and closes the exhaust port from the service cylinder to the atmosphere. The service magnet circuit is also closed, energizing this magnet, which in turn opens its valve. This allows the brake-pipe air to flow from the equalizing piston cylinder past the service magnet check valve into the brake cylinder. This port is choked down to the proper size to permit of a rate of brake-pipe reduction which will cause the equalizing piston and its slide valves to move toward their service application positions until the piston rests against its cylinder cap gasket; but this rate of reduction is not rapid enough to move the emergency piston and its slide valve, since under these conditions the quick-action chamber pressure can reduce through its feed groove as rapidly as the brake-pipe pressure is being reduced, consequently a service application is the result.

The first movement of the equalizing piston and graduating valve toward service position closes the feed groove, the emergency reservoir charging port, and the release piston port; opens the service port and allows the graduating valve cavity to connect the application end of the release piston and also the resistance-increasing cavity to atmospheric pressure, thus requiring a considerably greater differential in pressure than is needed with the type " P " triple valve for example, before the equalizing slide valve can be moved to service position. The object of this is two-fold: First, to reduce the sensitiveness of the valve sufficiently to prevent fluctuations in brake-pipe pressure, due to the feed valve or other causes, from producing undesired light service applications or brakes creeping on; second, to insure the making of such a brake-pipe reduction in applying the brakes that no trouble in releasing can result from inability to establish sufficient differential, as may be the case where the brakes will apply on a very light brake-pipe reduction.

This movement of the equalizing piston and graduating valve by connecting the application end of the release piston to the atmosphere causes same to move to application position in which the emergency reservoir charging, the service reservoir charging, the graduated release, the service reservoir, and the service cylinder exhaust ports are closed and the emergency valve port separated from the release slide-valve chamber and connected to the emergency valve exhaust port, which latter port is closed by the emergency slide valve.

The first movement of the equalizing piston and graduating valve toward release position, however, again exposes the friction-increasing cavity to auxiliary reservoir air. Thus the valve will be easier to release than to apply.

The further movement of the equalizing piston toward its service application position carries the equalizing slide valve to service position, in which the auxiliary reservoir air is free to flow past the end of the equalizing graduating valve through the service port into the service brake cylinder.

When the equalizing parts have moved to the service position, the equalizing slide valve has opened past its end the service reservoir port, so that the service and auxiliary reservoirs are connected, and the volume of these two reservoirs is such that from an initial pressure of 110 pounds, they will equalize with the service brake cylinder at 86 pounds.

The service port will remain open until the auxiliary and service reservoir pressure is reduced to a point slightly lower than that in the brake-pipe, when the equalizing piston and graduating valve will be moved back from service position until the equalizing piston rests against the equalizing slide valve (to lap position) and close same.

The service magnet may be held energized, thus holding its valve open and allowing the brake-pipe and brake-cylinder pressure to equalize, or it may be energized for only a portion of the time necessary to cause a full (equalized) service application, and thus cause a partial application of the brake, after which the parts will be moved to the service lap position, as above mentioned.

This energizing of the service magnet may be repeated several times, each time causing a further increase in the brake-cylinder pressure, until the final equalization of the auxiliary and service reservoirs into the service brake cylinder has taken place.

ELECTRIC EMERGENCY APPLICATION.

When it becomes necessary to stop in the shortest possible time, the brake-valve handle is moved to the emergency position and allowed to remain there until the stop is made and the danger has passed.

In this position the emergency magnet circuit is closed, energizing this magnet, which in turn opens its valve and allows the emergency piston cylinder air to flow through the emergency magnet port to the atmosphere; the emergency exhaust port of the brake valve is also open, but since the electric current travels so much faster than the reduction of air pressures, it is the electrical emergency that controls and applies all the brakes in the train simultaneously. The emergency magnet port is of such size as to permit of a rate of reduction which will cause the emergency piston and its slide valve to move over to the emergency position instantly. The equalizing parts will assume the same positions and perform the same functions as in service.

With the emergency piston and slide valve in emergency position, quick-action chamber air flows to the faces of the quick-action and switch pistons, moving these pistons so as to open the quick-action valve and close the emergency switch.

The quick-action valve and the emergency switch will remain open and closed respectively until the quick-action chamber can drain to the atmosphere through the small drilled port in the quick-action piston and the quick-action exhaust port, when they will be returned to their normal positions by their springs.

As previously stated, the release slide valve has the top of the emergency valve connected to the emergency valve exhaust, and this exhaust port is now open through the emergency slide valve to the atmosphere—thus emergency reservoir air, which is always under the outer area of the emergency valve, will lift same and flow into the emergency brake cylinder.

The first slight reduction in the emergency reservoir port will allow the emergency reservoir check valve to raise and connect the service and emergency reservoirs, and as soon as pressure builds up in the emergency brake cylinder, this air will lift the service brake cylinder check valve and allow the two cylinders to become connected. Thus the two reservoirs can equalize into the two cylinders in the shortest possible time.

With the emergency slide valve in the emergency position, the quick-action chamber exhaust port is open past the end of this slide valve through a port in the equalizing slide valve into the equalizing slide-valve chamber and the service reservoir. This port maintains the pressure in the emergency slide-valve chamber and holds this piston and slide valve in the emergency position.

ELECTRIC RELEASE AFTER A SERVICE APPLICATION.

When it is desired to release the brake electrically, the brake-valve handle is moved to the electric release position, in which the release magnet circuit is open, de-energizing this magnet and allowing its valve to open.

The brake-pipe port in the brake valve is also open and is restoring the air in the brake pipe to its initial pressure. This increase in the brake-pipe pressure forces the equalizing piston and its slide valve back to their release positions, in which the release end of the release piston is connected to the atmosphere and the port leading to the application end is closed by means of the equalizing slide and graduating valves, and, since the emergency reservoir is always connected to the release slide-valve chamber, the pressure in this chamber will force the release piston to the right and thus connect the service cylinder to the atmosphere, through the release magnet port and valve.

With the release and equalizing valves in release position, the emergency and auxiliary reservoirs are again connected, thus giving the quick recharge of the auxiliary reservoir. The service reservoir charging port and the auxiliary reservoir port to top of charging valve are also open, so that when the air in the auxiliary and emergency reservoirs is nearly to initial pressure, this valve will move downward and open the service reservoir port and allow the latter to be charged to the initial pressure.

ELECTRIC RELEASE AFTER AN EMERGENCY APPLICATION.

After an emergency application, the equalizing, release, and emergency pistons and their respective slide valves will remain in their emergency positions until the brake-pipe pressure is restored, as will also the protection and emergency valves. Then, with the brake-pipe pressure gradually increasing, the protection valve and the emergency piston and slide valve will be the first to go to their normal (release) positions, then the equalizing and release pistons and their slide valves.

With the equalizing slide valve in release position, the quick-action chamber exhaust port is open to the atmosphere, and, with brake-pipe air on the face of the emergency piston, this piston and valve are moved to the release position, thus opening the emergency cylinder exhaust and closing the quick-action chamber exhaust.

The equalizing slide valve also has the release end of the release piston open to the atmosphere, and the application end port closed, so that the release slide valve is also returned to the release position, allowing the service cylinder air to exhaust to the atmosphere, and opening the various ports, as under electric release after a service application.

ELECTRIC GRADUATED RELEASE.

The release of the brake may be graduated electrically by moving the brake-valve handle between electric release and electric lap positions. The brake-pipe port is open in the first of these positions; therefore, all the moving parts of the equalizing portion of the valve will be moved to their release positions, but the release magnet valve will be opened and closed, thus controlling the release of the service cylinder air.

In the above operation the emergency reservoir, which still has initial pressure, is connected to the auxiliary; the brake cylinder pressure will be reduced a few pounds at each graduation; but the exhaust port stays open only until the auxiliary reservoir pressure is slightly higher than that in the brake pipe, when the pressure in the former will move the equalizing piston and graduating valve back from their release position to graduated release lap position, when the release end of release piston port is lapped, and the application end of the release piston port is opened to the atmosphere by the equalizing graduating valve. These ports opening and closing respectively, cause the release piston to move toward the right and cause its slide valve to close the service cylinder exhaust, when no further reduction in brake cylinder pressure can occur until the brake-pipe pressure is further increased, or leakage reduces the auxiliary reservoir pressure, when the above operation will be repeated.

PNEUMATIC OPERATION.

The brake valves used with this equipment have the same position for either electric or pneumatic applications; the brake valve is provided with an equalizing reservoir and piston similar in all respects to those of any automatic brake valve. Thus, should the rate of brake-pipe reduction made by the service magnet valves not be as rapid as the reduction of the equalizing reservoir through the preliminary exhaust port, the equalizing piston will lift, opening the equalizing discharge valve, and bring the rate of reduction up to the required amount. This feature is also a telltale, and should warn the operator of any inoperative magnets. For example, in case the electrical features of the control valve or of the entire train brake system should be rendered inoperative through the loss of current, breakdown, etc., the brakes can be operated pneumatically (and will so operate automatically, whether the operator is aware of the fact or not). For example, should one service magnet in a train become inoperative (unknown to the motorman), the brake-pipe reduction made by the magnet valves that are operative will cause the control valve with the defective service magnet to operate pneumatically.

Similarly, should the electric control of the entire brake system fail because of loss of current or other reason, the brake valve would automatically assume the functions of an ordinary pneumatic automatic brake valve and cause the triple valve to operate automatically, by making a brake-pipe reduction through the operation of its equalizing piston and equalizing discharge valve in the usual way.

In pneumatic service operation the brake-pipe reductions would be made entirely by means of the brake valve, while in pneumatic emergency operations the brake-pipe reductions would be produced by the brake valve and the quick-action portions of the triple valves all operating together, as with the old quick-action automatic brake.

PNEUMATIC SERVICE APPLICATION.

When a pneumatic service application is desired, the brake valve is moved to the same position as for electric service application, but the electric control is now assumed to be inoperative. The brake-valve parts then operate as any brake valve containing an equalizing piston and discharge valve, opening a port from the brake pipe to the atmosphere, which will allow a rate of brake-pipe reduction sufficiently rapid to move the equalizing parts of the control valve to their service application positions, which will, in turn, actuate the release parts, close the service cylinder exhaust port, and cause a pneumatic application of all the brakes in the train in the usual way. A partial or full pneumatic service application and the holding of the brakes applied until a further application or a release is desired are accomplished as with any ordinary pneumatic brake.

The above rate of brake-pipe reduction, however, as fixed by the brake valve, is less rapid than that with which the quick-action chamber pressure can be reduced through its feed groove into the brake pipe.

The flow of air from the auxiliary and service reservoirs to the brake cylinder, and the operation of the release piston are the same in pneumatic as in electric service operation.

PNEUMATIC EMERGENCY.

When it becomes necessary to stop in the shortest possible time, the brake-valve handle is moved to the emergency position and allowed to remain there until the stop is made and the danger has passed.

In this position, the emergency exhaust port of the brake valve is open, and permits of such a rapid rate of brake-pipe reduction that the quick-action chamber pressure in the first triple valve in the train cannot reduce through its feed groove as rapidly as the brake-pipe pressure is being reduced through the brake valve, and, consequently, forces the emergency piston and its slide valve to move over to their emergency positions. The equalizing parts have also been moved over until the piston rests against its cylinder cap gasket.

The operation of the various valves is now the same as described under the "Electric Emergency Application."

In case the train should separate (the electric control of the brakes being in working order) the electric emergency would prevail on the forward end (due to current still being applied) and pneumatic emergency on the rear end (due to current being cut off by the separation).

PNEUMATIC RELEASE—GRADUATED.

When graduated release is desired the direct and graduated release cap must be placed in the graduated release position, as shown in the section. In this position of the cap the emergency and auxiliary reservoirs are connected when the release slide valve is in release position.

With the electrical portions inoperative, the release of the brake may be graduated as with any ordinary pneumatic graduated release brake, by moving the brake-valve handle to running position for a few seconds and then back to lap position. This will cause a slight increase in the brake-pipe pressure and move the equalizing parts to release positions, and this, in turn, will move the release parts (in lap position of the brake valve the brake-pipe port is closed, and, consequently, only a few pounds increase in brake-pipe pressure will result), but with the release parts in release position the emergency reservoir port is open, and, since this volume is not used in service operations, it will still have its initial pressure. The emergency reservoir air will now flow back into the auxiliary reservoir, and quickly raises the latter pressure to a point which is higher than that in the brake pipe, and consequently will move the equalizing piston and its graduating valve back from their release to their graduated release lap positions, in which the release end of the release piston is open to the atmosphere and this piston and valve are moved to the application position in which the service cylinder exhaust port and the ports which connect the emergency and auxiliary reservoirs are closed, thus preventing a further increase in auxiliary reservoir and a further decrease of service brake cylinder pressure. During the time that the emergency reservoir port is open, allowing its air to flow back into the auxiliary reservoir, the release ports are connected, allowing a portion of the air from the service brake cylinder to flow to the atmosphere.

A further reduction of brake cylinder pressure cannot now be made until the brake-pipe pressure is again increased and the equalizing piston and its graduating valve moved to release position, when the above operation will be repeated.

The graduation of the release may be repeated until the brake-pipe, auxiliary, and emergency reservoir pressures are equalized, when the valves will remain in the release position and give the final release of brake cylinder pressure.

PNEUMATIC RELEASE—DIRECT.

If cars equipped with this valve are used in a train with cars that do not have the graduated release feature, the direct and graduated release cap should be set for direct release position, in which the emergency and auxiliary reservoir ports are separated, and the emergency reservoir cannot then flow back into the auxiliary reservoir when the parts are in release position.

Under these conditions, if the brake-valve handle were placed in running position for a few seconds and then in lap position, there would be no source of supply of air at a higher pressure (as furnished by the emergency reservoir in the case just described) to cause a return of the equalizing parts to graduated release lap position, and, consequently, a straightaway release of the brake cylinder pressure would occur.

PROTECTION FEATURE.

Should the motorman make an application and then let the brake-valve handle remain in lap position, the brake-pipe leakage would first cause the brake to equalize, and then, when this leakage has reduced the brake-pipe pressure to a certain predetermined point (which is governed by the tension on the protection valve spring), the protection valve will be moved from its seat and toward the right—this allows the quick-action closing chamber port to be connected to the quick-action and emergency switch piston ports and causes same to open and close respectively, which causes a venting of brake-pipe air to the atmosphere and also the instantaneous quick action or emergency, due to the emergency magnets being energized by the closing of the emergency switch.

Under these conditions the equalizing and release pistons and slide valves are already in the emergency position (which is the same as for service), and the opening of the emergency magnet valve causes the emergency piston and slide valve to move to the emergency position, and this, in turn, opens the emergency valve, and the reservoirs equalize with the brake cylinders, as hereinbefore described.

REDUCTION LIMITING FEATURE IN THE EQUALIZING PISTON.

Ordinarily, the service magnet makes a brake-pipe reduction by connecting the brake pipe to the brake cylinder: this then means that these two pressures are approaching each other, and as they near the equalizing pressure the rate of reduction in the brake pipe is gradually decreasing to zero.

In order to procure the desired pressure in the given time, then, the rate of reduction at first is quite rapid and the margin between it and the emergency rate is very small, and this margin is broadened as equalization is approached.

For those who may desire to have a uniform margin between the service and emergency rates of reduction, provision has been made to close the service magnet connection to the service brake cylinder and open same to the atmosphere. Then in order to limit the brake-pipe reduction to the equalization point, the reduction limiting check valve is embodied in the equalizing piston.

When the service magnet valve is open and the equalizing piston is moved over toward service position, the reduction in auxiliary reservoir pressure which follows the opening of the service port stops the movement of the equalizing parts before the reduction limiting check valve seats against the cylinder cap gasket.

If a continuous brake-pipe reduction is made, the equalizing parts will remain in this position until the auxiliary reservoir and brake cylinder pressures have equalized; then a further reduction in brake-pipe pressure will cause these parts to be moved by the higher auxiliary reservoir pressure until the reduction limiting valve seals against the cylinder cap gasket, thus preventing an over-reduction in brake-pipe pressure.

To sum up the requirements and considerations of the electro-pneumatic brake equipment, we present the following:

1. *Fundamental Principles Relative to Electric Control of the Automatic Brake.*

1. The electric control system must not, either in its proper or improper action, or in its failure to act in any way, impair the stopping power of the automatic brake system.

2. During electrical control of brake applications, loss of current must not cause loss of braking power already obtained.

3. The opening of the application magnet valves must invariably be accompanied by the closing of any possible outlet to the atmosphere.

4. The application and exhaust magnets of the electric brake must be cut off from connection with the atmosphere when the brake is applied automatically.

5. The design of the electric brake should be such that it purposely actuates the control valve as with a pneumatic application, and a brake-pipe reduction must be made approximately equal to that required for an automatic application; that is to say, the operation of the electro-pneumatic brake must be as nearly as possible the equivalent in all particulars of the operation of the automatic brake.

6. The electro-pneumatic system is best which uses the same positions of the brake valve as the pneumatic and operates the brake in the same way.

7. The electro-pneumatic quick-action emergency is essential to the safety of modern trains and traffic; therefore, such a reserve of air must be preserved as will permit of an emergency application at any time.

2. *Battery Current.*

Battery current is considered fundamentally desirable to the satisfactory operation of the electric control of brakes, because of its reliability, uniformity, and availability. It is immaterial how the battery is charged, provided it is of ample capacity.

3. *No Current at Brake Valve Unless All Jumpers in Place.*

The wiring scheme should be such that the fact that current is obtainable at the brake valve indicates in itself that all the jumpers are properly in place throughout the entire train; an interrupted control current is, in a degree, analogous to a closed angle cock in the brake pipe.

4. *Protection of Batteries.*

In steam road service, with means of obtaining the current from the car lighting systems, a device must be provided to prevent inadvertently cutting the brake supply wires on to more than one source of electrical energy at the same time.

5. *Train Signal.*

Electric operation of the train signal should be considered a part of the electro-pneumatic brake system.

6. *Universality of Equipment.*

Until recently the entire development of the automatic air brake has been along the lines so admirably laid down at the beginning by Mr. George Westinghouse, and each new form of equipment has worked in harmony with its predecessors. Owing to the enormous investment involved and the wide interchange of equipment throughout the country, this procedure has been of incalculable value to the railroads, and in the radical change in the method of control of the automatic brakes that we are considering it would seem to be equally necessary that this important principle be followed. It, therefore, is greatly to be desired that any new equipments be operative on their strictly pneumatic side with the present forms of automatic brake, during the necessarily very long transition period, and that the one or more systems of electric control that may have to be used must be interchangeable in their operation. This, however, should not be understood to exclude special installations such as now have (or may have) to be made with pneumatic brakes, where interchangeability is not to be considered because of the isolated and local conditions.

7. *Electro-Pneumatic Brake Versus an Electrically-Controlled Automatic Air Brake.*

The ideal electro-pneumatic brake is one in which all functions are controlled electrically and the compressed air serves only as the medium of power transmission. Cars equipped with such a system would not be interchangeable with those having the present automatic brake, consequently the first essential would not be fulfilled, and to accomplish this the parts required to make an automatic air brake must be added. Again, in order that an electric system of control shall, in itself, be absolutely dependable, it is necessary that, as with the air control, loss of the controlling element shall set the brakes. Our experience with a purely electric system of control tested on the Boston Elevated Railway, in 1909, demonstrated that there were many ways in which the controlling element could be lost without manifesting the location of the cause, which in the case of air is so readily determined from the noise made when escaping. Hence such a system of electric control might necessitate the presence of an electrician on each train to promptly locate the cause of a loss of current or the installation of automatic indicators. As the air supply comes from the locomotives, a pipe to conduct the compressed air to the cars is necessary in steam train service. Such being the case, loss of air from the pipe of the brake system is with any design available to set the brake if the train breaks in two. At present, therefore, the practical electric control of the brakes must necessarily be built upon the automatic air brake as a foundation, and only such a system has been considered or advocated in this paper.

8. *Fundamental Requirements of a Brake.*

Among the fundamental improvements to the present pneumatic brake before it is wise to instal the electric features are that the emergency application be

First.—More quickly obtained than has been the case.
Second.—More powerful.
Third.—Obtainable at any time.

The Westinghouse Air Brake Company and the engineers of some of the railroads have taken the stand (1) that it is fundamentally necessary that the difference in time between the attainment of full cylinder pressure in service and emergency application *should be* the *greatest attainable* (assuming that the ready service application is as high as practicable; while (2) the difference in force should be at least 100 per cent.

9. *Relation of Electric and Automatic Emergency Applications.*

Since there can be only three objects in adding electric control to the automatic air brake, namely,

First—Increased safety (emergency);
Second—Reduction in time required to make stops (service);
Third—Instantaneous and simultaneous response and uniform application whereby the human equation relating to the manipulation is reduced to a minimum;

it follows (1) that the automatic air brake must be equal to the electric in every feature of emergency application, except that of time; (2) that no logical reasoning can justify the application of electro-pneumatic brake unless the preceding requirement is observed; (3) that an automatic air brake inferior to the electric is likely to be dangerous to a degree approximating the difference between the effectiveness of the electro-pneumatic brake and the automatic air brake, and, where great inferiority of the latter brake exists, the chances for disaster (when the electric control is inoperative when attempt is made to use it) are greater than if no electric control of the brake is employed, unless, of course, the same distances for signals, etc., be allowed as though the electric feature did not exist. (See curves on pages 132 to 140 inclusive of the August issue.)

10. *Rate of Emergency Application.*

In emergency applications maximum braking power should be obtained in the shortest possible time consistent with practical construction; this applies to both rate of transmission and rise of cylinder pressure. In other words, it is not sound engineering to add the electric control to a pneumatic brake until everything practical has been obtained by proper design and installation of the pneumatic devices.

(By sound engineering is meant the best for the purpose (by purpose is meant the shortest practicable stop); but it does not follow that some compromise may not be best for the conditions.)

11. *Braking Power.*

The forces delivered to the brake shoes in emergency application should be at least 100 per cent. greater than that normally provided for in the design for the service brake.

12. *Extent of Electric Control.*

Use of electric control can be made in three ways—and this manifestly whether the improved pneumatic brake is used or not:

First.—To apply to both the service and emergency functions of the automatic brake.
Second.—To the emergency functions only.
Third.—To the service functions only.

In the first, the effect will be, as far as stopping distance is concerned, to leave the service and emergency brakes relatively the same as at present, and this applies, no matter whether the electric is applied to the old or improved forms of pneumatic brakes; the gain, however, will be two-fold. First, both the service and emergency stops will be shortened because of the elimination of the time element in getting the brake application started; and, second, shocks will be eliminated because of the simultaneous application of the brake.

In this connection it should be understood that the application of the electric control to any form of pneumatic brake will insure freedom from shocks, but if safety is the chief desideratum, this can be had to a much greater degree and for less expense than is possible by the mere application of electric control.

If applied as per No. 2, the gain will be, first, somewhat greater safety due (*a*) to the simultaneous application of the brakes, (*b*) to the reduction of shocks, wheel sliding, etc., and (*c*) to the increase and effectiveness of the emergency brake over the service brake; second, the elimination of damaging and discomforting shocks so far as emergency application is concerned.

If applied to the third, that is, to the service functions only, the gain will be in the saving of time to get the brake applied, and in the elimination of shocks and discomforting surges, so far as service applications are concerned. However, the application is undesirable from the fact that it reduces the margin between service and emergency stops; in fact, it is possible to so make the installation that the electrically-controlled service stop would be shorter than if the stop was made with the strictly pneumatic emergency application.

Therefore it will be seen that an electric pneumatic installation in which the service application of the brake approximates in efficiency that of the pneumatic emergency is strongly defective.

From these considerations we conclude, first, that the greatest gain in every way can be had by adding the electric control to the most improved form of pneumatic brake; second, that it should be applied to both the service and emergency functions of the brake; and, third, that it should not be applied to the service brake only, but may be applied with considerable gain to the emergency brake only; and, fourth, that the application of electric control to the brake will contribute to safety, economy, and comfort to a degree impossible of attainment with a strictly pneumatic brake and to an extent far beyond any consideration of expense or complexity.

It is seldom that any one device or appliance offers the solution of so many problems, overcomes so many difficulties, and at the same time utilizes such a vast energy that now is dangerous or goes to waste.

This system eliminates time so far as brake initiation and propagation are concerned.

It eliminates retardation shocks, since it reduces brake operation closely to the effects as though one vehicle only was being retarded.

It reduces the human equation to a very low factor, as it is so promptly responsive and flexible that correction of errors of judgment in manipulation can be made before inconvenience or damage can occur.

It is free from many of the shortcomings of other brake equipments, special care being taken to insure its immunity from influences (which unavoidably exist) that cause brake operations contrary to what are contemplated or when not desired.

It increases the safety of train operation, because full emergency braking force is available and obtainable always and instantaneously effective.

For "service" (station stops, etc.) operation, it is especially valuable from a revenue standpoint, as it permits of stops being made in much less time with a reliability, smoothness, and accuracy heretofore impossible.

It permits of accurate, instant, and comprehensive communication between the engineer and train crew, or *vice versa,* thus contributing largely to coöperation and efficiency.

It combines in one brake or train control equipment the two elements (compressed air and electricity) that seem intended to complement each other for this purpose; and, since the combination has proved in practice to be fully equal to its theory, it can hardly be called prophecy to say that its potentiality will be taken advantage of as it becomes known.

It is reliable, adaptable, and complete, and the writers have endeavored to so carefully and fully set forth the system as to permit those interested or concerned to verify all that is claimed for it. If this is accomplished, our purpose is served and much progress in this important and difficult field will have been made.

Federal Aid for Vocational Education.—This subject will be discussed at the annual meeting of The National Society for the Promotion of Industrial Education, to be held in Philadelphia on December 5, 6, and 7, 1912. Among the speakers are Ex-Senator A. J. Beveridge, Julia C. Lathrop, Hon. Caroll S. Page, author of the Page Bill, E. Geier, and others.

The different sessions of the society will be devoted to proposed legislation in vocational education, securing teachers for vocational work, vocational education in State and local communities, and many other topics of interest to manufacturers and educators.

PLATINUM: THE MOST PRECIOUS OF THE METALS.[1]

BY

HARRY F. KELLER, Ph.D.,
Member of the Institute.

When I received the invitation to contribute a lecture to this season's programme of the Chemical and Physical Section, my thoughts, by reason of several circumstances, were so engrossed with the subject of platinum that I somewhat rashly promised to give a lecture on this in no sense novel theme.

Under the stress of other duties, I had almost forgotten my promise, when, about a month ago, I was informed that this evening had been assigned to me, and I was thus aroused to give some serious consideration to the task I had undertaken. Platinum! Of all subjects, why had I selected *it?* What new and interesting advances in our knowledge of the metal would justify my discussing it before an audience such as this?

On further reflection, however, it occurred to me that several reasons might be advanced in favor of my selection. In the first place, platinum, by virtue of many new applications in the arts, had become a subject of popular interest; secondly, that chemists, though constantly handling utensils made of the metal, are only in exceptional cases obliged to acquaint themselves with the special literature of the subject; and, thirdly, that the platinum group of metals, being almost invariably relegated to the last place in systematic courses in inorganic chemistry, is generally very briefly dismissed or not even reached in the lectures on this branch of chemistry.

In my own case platinum and the allied metals came into my range of interest very early in my scientific career, but for a number of years my interest in them had remained dormant until, some time ago, it was reawakened—first, by some assays and experiments which I made for a client, and again, in a rather unpleasant way, by an occurrence in the laboratory of the Central High School.

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[1] Presented at the meeting of the Section of Physics and Chemistry held Thursday, April 11, 1912.

As you know, platinum vessels are extensively used in chemical experimentation and analysis. They constitute the most expensive part of the equipment in the chemist's workshop. As most of them are of small size, you will readily understand that in a laboratory to which many and all kinds of people have access the safe keeping of the platinum-ware not only necessitates special precautions, but also causes some anxiety now and then to those charged with it. Thus, in spite of the most explicit instructions, it will happen that a novice puts a platinum crucible out of commission while the instructor turns his back to him; and a fifty-dollar platinum dish may disappear from a desk as if it were made of the most volatile of substances.

I have been accustomed to handle and take charge of platinum apparatus of many descriptions and considerable value for a period of over thirty years. I had it impressed upon me with the first crucible I bought as a student that platinum must be treated with proper respect, and I have been fortunate in so far as I have never ruined a piece of platinum myself. There have been a few instances in which crucibles were damaged by students working under my direction, but until recently no theft of platinum had occurred in our laboratory, except, about a year ago, that of a small dish. Last fall, however, we had an experience which taught me that in addition to constant vigilance there is another precaution one cannot afford to neglect in taking care of the platinum stock of a large laboratory, and that is to keep it in a burglar-proof safe.

What happened then was briefly this. Returning to the school after an absence of several days, I opened the drawer in which I kept the platinum for general use in the laboratory, and discovered, to my amazement, that two of the larges dishes, worth at least $250, were missing. Otherwise the contents of the drawer, which contained many other platinum utensils, had not been disturbed, and the lock was perfectly intact. As the laboratory doors are always locked during the absence of the instructors, and only a few trusted employees of the school have access to these rooms, I was at a loss to account for the theft. I immediately reported the loss to my superiors, and with their approval, took what I considered the proper steps to recover the stolen articles. I furnished a description of the latter to all the principal dealers of platinum goods, and called on the Chief of the city's Detective Bureau, who promptly detailed one of his best men on the case, and also had my description of the dishes printed and sent out to the "old gold" and pawnbroker shops in the city. Three days later the detective called me up on the telephone and informed me that the "cups" had been found, and that I should call for them at the City Hall. You can imagine how relieved I felt when the precious pieces were safe and sound in my hands once more, and without any expense for their recovery.

Just how the theft was committed is still a mystery. The dishes had been offered to a local dealer in "old gold," who at once suspected that they had been obtained in some dishonest way, and had cleverly managed to get possession of them without directly paying the money asked by the thief and his accomplice. On receiving the notice he turned the articles over to the Detective Bureau without asking for any reward. The description of the person who offered the platinum for sale, together with other evidence found later, leaves little doubt as to who the thief was, but an unfortunate combination of circumstances frustrated his identification.

My reason for prefacing my lecture with this incident is twofold: it shows that we cannot be too careful in providing a safe place for the keeping of our platinum-ware, and it may afford some useful hints as to what course to pursue in the event of a theft.

Let us now take up our subject in a methodical way, and begin in the good old-fashioned manner with an historical sketch.

Unlike most of the useful metals, platinum remained unknown until comparatively recent times. Probably the earliest authentic reference to it is to be found in a work of Antonio de Ulloa, a Spanish naval officer, published in 1748, and entitled "A Narrative of a Journey to South America." In this Ulloa mentions it under the name of platina as a mineral which occurs in the Choco District of Colombia, and which is found admixed to the gold of that district. He describes it as an extremely tough substance that renders gold unworkable, as it cannot be extracted or removed by any of the ordinary processes.

Specimens of platinum, probably from the same source, were brought to England as early as 1735 by Charles Wood, who obtained them at Cartagena, in Colombia. William Brownrigg, who received some of this material from Wood in 1741, and published a description of it as a metalloid in 1750 (two years later than Ulloa), is now generally credited with the discovery of platinum. For many years it was erroneously ascribed to William Watson.

A more complete investigation of platinum was made by Scheffer, assayer of the Stockholm Mint, and the results were communicated to the Royal Academy of Stockholm in 1752. His material came from the gold-bearing sands of the river Pinto, in Colombia, and he called the new substance "white gold, or the seventh metal, known in Spain as *platina del Pinto.*" Scheffer showed that platinum is a true metal, insoluble in nitric acid, but soluble in aqua regia; also, that it is infusible at the highest temperatures attainable in furnaces, but capable of forming fusible alloys with other metals and with arsenic.

Fairly pure platinum was first obtained by the German chemist Margraf, who made the important discovery that solutions of platinum chloride are precipitated by potassium and ammonium salts, but not by sodium salts. He also was the first to prepare spongy platinum. In 1778 the Count von Sickingen communicated to the French Academy the results of his experiments with platinum, in the course of which he found that the metal can be welded, and that it can be worked into foil and wire. A new process of rendering platinum malleable, by treatment with arsenic, was described by Achard in 1784. Macquer and Baumé succeeded in melting platinum in the focus of a powerful concave mirror. But in spite of all the work that was done on platinum during the latter part of the eighteenth century, it was not until the beginning of the nineteenth, and chiefly through the labors of certain Englishmen, that it yielded to metallurgical treatment and became a commercial product. In 1819 platinum was discovered in the gold placers of the Ural Mountains, and a few years later Russia became the chief source of commercial platinum.

The most important developments in the platinum industry were the perfecting, by Wollaston, of a process of making malleable platinum from the pure spongy metal, and the achievement of Deville and Debray, in 1858, of devising a process by which large quantities of the metal can be melted.

Owing to a rapidly increasing demand and a nearly stationary supply, the value of the metal has enormously increased in recent years, so that during the first decade of the present century the price of platinum has not only surpassed but more than doubled that of gold.

PLATINUM MINERALS.

In my experience as a teacher I have found that few words are so commonly misunderstood and incorrectly used as the simple term mineral. I may be pardoned, therefore, if I preface my description of the platinum minerals with a brief explanation of its meaning. In the popular sense we speak of minerals, or mineral products, to designate those materials which make up the solid crust of the earth, or which are taken out of "the bowels of the earth," in contradistinction to those which are derived from the animal and vegetable kingdoms. In the more specific sense, however, in which the term is employed in science, a mineral is a naturally occurring inorganic substance, having a definite chemical composition and definite physical characters, the essential feature being its homogeneity.

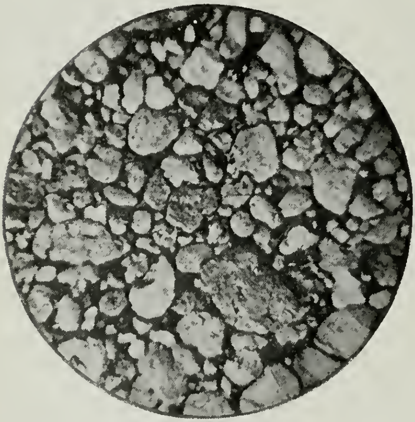
Now suppose we found such a natural substance to contain platinum and that this metal formed an essential part of its composition, we would then speak of this substance as a platinum mineral, and if it contained the metal in sufficient amount to permit of its commercial extraction, we would call it a platinum ore.

The mineralogy of platinum is extremely simple; for there are but a very few minerals that contain the metal, and only one of these constitutes an ore, and that is the *native platinum* from which the commercial metal is exclusively obtained.

But, although native platinum is not chemically combined with any other elements, it nevertheless invariably contains a number of other metals which are mixed or alloyed with the platinum. Among these must be mentioned five rare metals which are closely related to platinum, namely, iridium, rhodium, palladium, ruthenium, and osmium, as well as the more familiar ones,—iron, copper, and gold. For the reason that native platinum is always host to a number of such guests or strangers, it has also received the name of *polyxenite,* meaning many strangers.

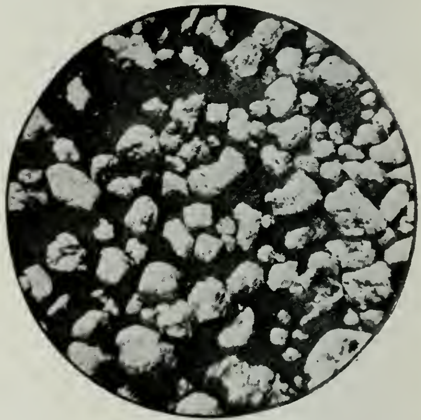
Native platinum occurs mainly in river sands and alluvial deposits, in the forms of grains, scales, and nuggets; the grains, though usually worn and rounded (Fig. 1),* not infrequently show distinct cubical crystallization (Fig. 2). The nuggets are usually small, though masses of considerable size, weighing up to 20 pounds, have occasionally been found in different localities (Fig. 3).

FIG. 1.



Thin, worn platinum grains, Colorado River, Colombia.

FIG. 2.



Rough unworn platinum grains, Tulameen River, British Columbia.

Owing to their exceptional occurrence, the larger nuggets have mostly found their way into collections of minerals.

Apropos of this, I can tell you an amusing anecdote, one of the few I have heard in connection with platinum. It is from Lewis's "Life of Goethe," and runs something like this: In the twenties of the last century a large and fine specimen of native platinum was included in a consignment from the Czar to the court of Saxe-Weimar, with the instruction that the specimen be forwarded to Doebereiner, then Professor of

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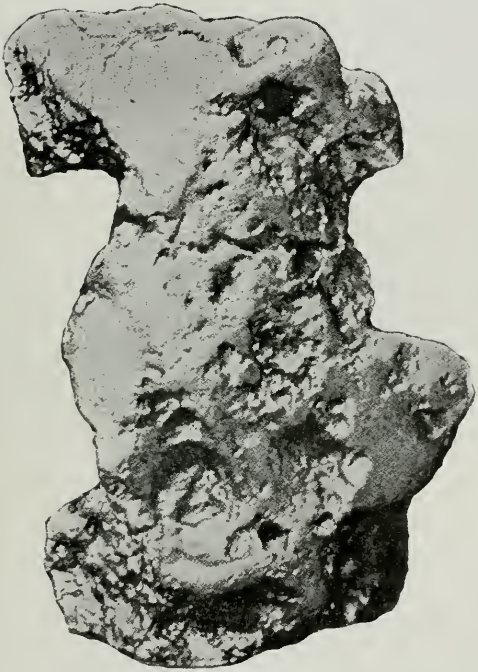
* My grateful acknowledgments are due to Professor James Furman Kemp for kindly permitting me to copy this and other illustrations from his monograph on platinum and associated metals. U. S. Geological Survey Bulletin No. 193.

Chemistry at Göttingen. It was, however, first submitted to Goethe, friend and Prime Minister of the Duke, as well as an ardent collector of minerals. The poet took such a fancy to this curiosity that he quite forgot to return it or send it to its destination. Doebereiner, worried over the non-arrival of the promised treasure, wrote to Goethe, courteously inquiring as to what had become of it. He received no reply either to this or to the more urgent inquiries that followed; so, as a last resort, he wrote directly to the Duke, imploring him to order Goethe to surrender the specimen. This was the reply: "Why bother the old fool? I will write to my brother-in-law, the Czar, and he will be pleased to send you another and even finer nugget."

FIG. 3.



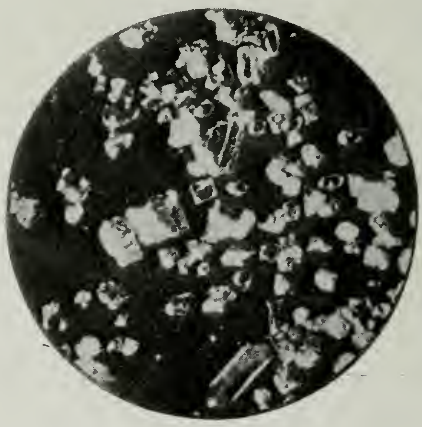
Nugget of platinum, weighing 14 pounds, found at Nizhni Tagilsk in 1894.

Native platinum has a grayish-white or gray color, and strong metallic lustre. It is malleable, and harder than gold or silver. Its specific gravity varies within wide limits, say from 14 to 19, owing to the presence of iron and other metals. Some varieties are strongly magnetic, even showing polarity, while others are scarcely attracted by the magnet.

The chemical composition of native platinum from various localities is shown in the analyses given in Professor Kemp's admirable bulletin. The platinum content varies from 51.5 per cent. to 86.5 per cent., while the remainder is made up mainly of iron and the other platinum metals.

When the mineral contains very large proportions of iridium, so that the latter metal preponderates, it is called platiniridium.

FIG. 4.



Sperrylite in cubes from Vermillion Mine, Ontario.

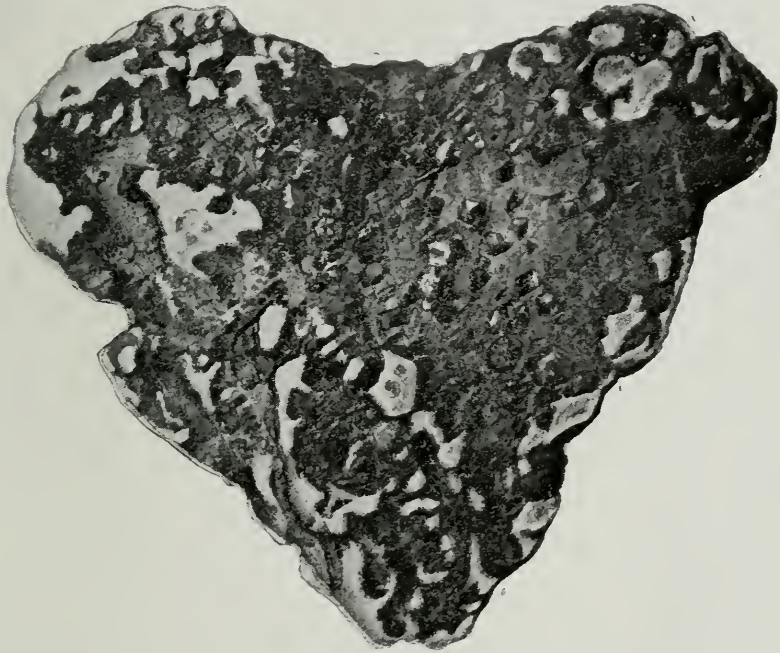
This variety, which may contain over 75 per cent. iridium, is extremely rare. It is whiter and harder than platinum, and is the densest of all minerals, its specific gravity being nearly 23.

Small proportions of platinum are found in a few rare minerals, such as *native palladium* and *iridosmine*. The only known compound of platinum that has so far been met with in Nature is *sperrylite*, an arsenide of the metal, $PtAs_2$. It is likewise a very rare mineral, and has been found only in a few localities, notably in a copper mine near Sudbury, in the western part of Ontario (Fig. 4).

Sperrylite forms very small, shining crystals, similar to those of pyrite. It is hard and brittle, and has the specific gravity 10.6.

In addition to the true platinum minerals, some other minerals which are commonly associated with native platinum in the gravels, and often attached to the nuggets, should be mentioned here. It is through studying these associations that geologists may expect to find clues as to the original home of the metal in the mother rock. The most important of these companions of platinum are chrome iron, olivine, serpentine, pyroxene, and native gold (Fig. 5).

FIG. 5.



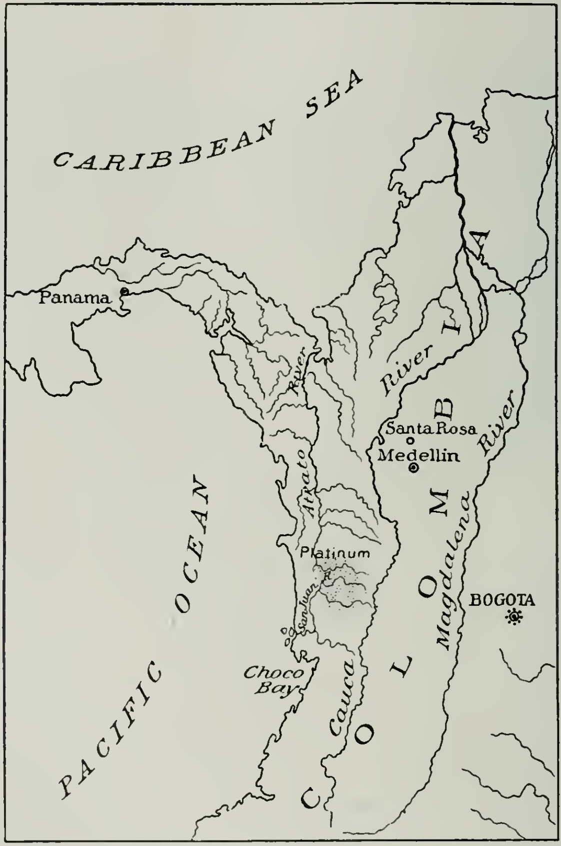
Platinum nugget with olivine and octahedral chromite, Tulameen district, British Columbia (after Kemp).

These and a number of other dense and hard minerals which accompany the platinum are the same as those usually found in the gold-bearing gravels and sands, and must be regarded as fragments worn away from the rock in which these metals were originally deposited.

A very complete and thorough discussion of the work done can be found in Professor Kemp's bulletin on "Platinum and Associated Metals," published in 1902. According to Professor

Kemp, this has been accomplished in a few instances, but the quantities of platinum that have been found in the country rock are so small that the commercial extraction of the metal from such rocks is out of question. My own experience seems to confirm this.

FIG. 6.



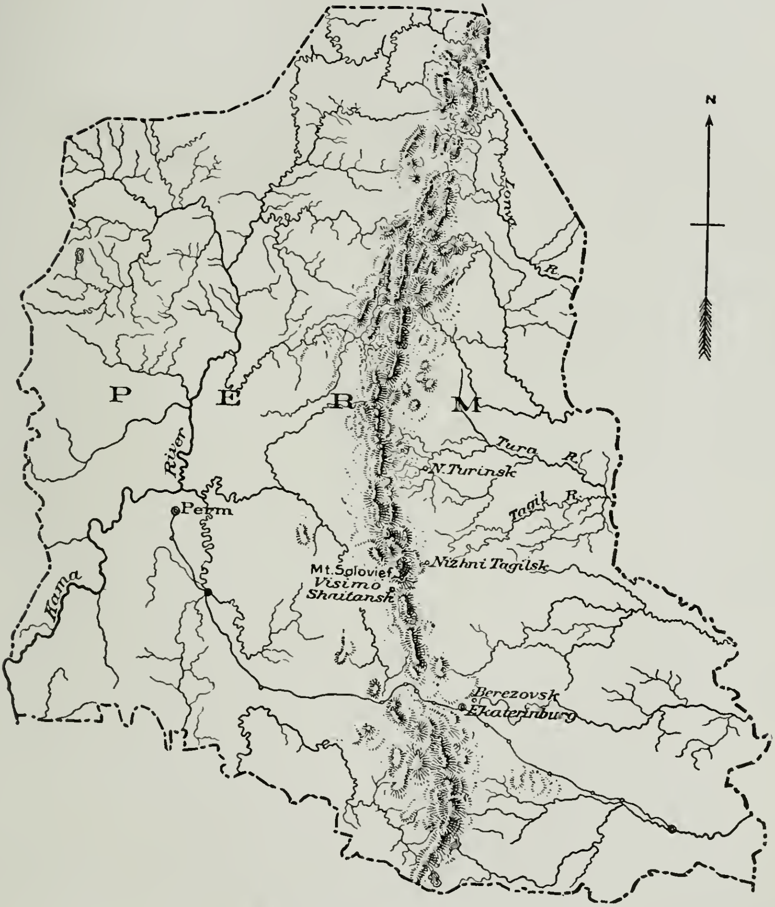
Map of Colombia.

SOURCES OF COMMERCIAL PLATINUM.

While native platinum has been reported from many and widely scattered localities, both of the Eastern and Western Hemispheres, the districts which have produced the metal in commercial quantities are few in number and limited in extent.

As I have stated before, platinum was first observed in the gold placers of Colombia. The river Pinto, from the sands of which were obtained the first specimens that were brought to Europe, is doubtless one of the tributaries of the San Juan, in the district known as El Choco (Fig. 6). Before the discovery of platinum in the Ural Mountains, Colombia furnished the bulk of the metal of commerce, and, while its production at the present time is probably only one-twentieth that of Russia, it still occupies the second place as a platinum producer. It is

FIG. 7.



Map of the Government of Perm.

estimated that Colombia has yielded over 50,000 pounds of platinum, mostly from the San Juan district.

Among the earlier finds of platinum, those made in the gold washings of the island of San Domingo, and especially the province of Minas Geraës, in Brazil, are often mentioned. It does not appear, however, that either of these localities has ever contributed appreciably to the world's supply.

It was not until 1819 that platinum was first observed in Russia. In that year small quantities of grayish-white metallic grains were gathered in the gold washings of Verk-Isetsk, in the Siberian Urals. They were not recognized as platinum until 1823. The development of the great deposits at Nizhni Tagilsk began in 1824, and in the following year the metal was found also in the Goroblagodat district.

Since that time the metal has been found in many other localities in the government of Perm (Fig. 7), but those which have produced the bulk of the commercial metal are in the districts southwest of Nizhni Tagilsk and northwest of Nizhni Turinsk. The Goroblagodat and Bisersk districts on the northeast of the latter place are at present the most active producers of the metal.

Outside of Russia and Colombia, platinum has been produced, though only in comparatively small quantities, in California, Oregon, Washington, British Columbia, Borneo, and New South Wales. Great efforts have been made in recent years to increase the output, especially in British Columbia and in New South Wales, but apparently without success.

EXTRACTION AND PURIFICATION.

Since the platinum of commerce is exclusively derived from alluvial deposits, the methods employed for its recovery are essentially similar to those employed in gold placers; indeed, if we except the Uralian districts, it may be said that platinum is generally obtained as a by-product in gold washing.

The Russian platinum-bearing gravels, which are covered with barren material, from a few feet to 50 feet in depth, are worked partly by open mining, but usually by sinking shallow shafts and drifting along the pay streak. The latter, as a rule, is only a few feet in thickness, and the gravels are said to run from .05 to 1 ounce per cubic yard.

The washing plants are mostly of a peculiar, rather primitive construction, though quite recently modern methods and apparatus have been successfully introduced on some of the properties.

(For descriptions and recent improvements in the recovery of platinum, with or without gold, see Mineral Resources, 1905–1906.)

The metal obtained by washing and various concentrating processes, and freed from gold, constitutes the crude platinum, or platinum ore, of commerce.

As we have seen, this contains various metals that render the platinum unworkable, and the ore has to undergo a refining process to convert it into the commercial form.

Many attempts to render platinum malleable and ductile were made during the latter part of the eighteenth century, and while a few men, like Achard, the Count von Sickingen, and the skilful metal workers Chabanneau and Jeannetty, of Paris, succeeded in doing it on a small scale, it was not until the early years of the nineteenth century that the platinum industry was really founded, and the creators of this industry were Englishmen.

About the year 1800 Charles Knight devised a process which, while still imperfect, embodied the principal features of the method by which all commercial platinum was obtained for more than fifty years. It consisted in dissolving the crude metal in aqua regia, precipitating the solution of the chloride with sal ammoniac, then packing the dried precipitate into conical moulds of fire clay, and strongly heating it in the mould. It is said that the metal was thus obtained as a coherent mass which could be hammered and worked into various forms.

The product, however, still lacked solidity and homogeneity, and it was only by certain important modifications and improvements that it became a commercial success. The improved process is usually credited to the chemist Wollaston, but according to Roscoe the main features were invented by a relative of a member of the firm of Johnson & Matthey. However that may be, it is certain that the improved process was first described by Wollaston in the Bakerian Lecture for 1828, and Faraday, who was undoubtedly well informed on the subject, said in a lecture on platinum, delivered in 1861, "This substance has been given to us hitherto mainly through the philosophy of Dr. Wollaston."

In the process described by Wollaston the double chloride of platinum and ammonium was very carefully heated to a temperature just high enough to expel the ammonium salt, whereby the cohering of the resulting particles of metal was prevented. The product was then rubbed by hand, sufficiently fine to pass through a lawn sieve. It was then made into a uniform pulp with water, and this was placed into a brass cylinder, where it was powerfully compressed by means of a lever. The hard cake which resulted was heated on a charcoal fire, to expel the water and promote cohesion, and finally heated at the highest temperature attainable in a wind furnace. By forging the white-hot cake under a heavy hammer, it was consolidated into an ingot, which could be beaten into thin sheets and drawn into the finest wire. The refractory natural product had been conquered, and henceforth platinum was one of the useful metals.

That platinum is not infusible was shown in 1758, when Baumé and Macquer succeeded in melting grains of the ore by the aid of a concave mirror; but the melting of considerable quantities of the metal was a feat which was first accomplished in our own city: in 1847 Robert Hare demonstrated that the difficult and tedious process of consolidating platinum sponge could be replaced by the simple operation of fusing the metal in the oxyhydrogen flame. He melted as much as two pounds of platinum at a time.

His process was greatly improved by the French chemists Deville and Debray, and it was through them that it became more generally known, and that it was adopted by the platinum refiners.

Deville's furnace consists of two well-fitting pieces of quicklime, hollowed out to form a crucible or hearth. An opening at the side serves as a spout for the molten metal and for carrying off the fumes and products of combustion. The nozzle of the oxyhydrogen blowpipe is introduced through an opening in the centre of the cover.

Lime is used because it is infusible at the temperature of the flame, and because it is porous and absorbs the slags formed during the operation. It is also a poor conductor of heat.

I had the privilege of seeing this process in operation at

WILLIAM HYDE WOLLASTON. M.D F.R.S.

WH Wollaston

the Heræus works at Hanau. Although they used illuminating gas instead of hydrogen, it was amazing to see the platinum sponge and scrap melt like butter as fast as it was fed in. You cannot, however, distinguish the metal from the lime, as both glow with the same intensity, and one must also protect the eyes with dark glasses when looking into the furnace. At the Heræus works I was shown all the principal operations, from the treatment of the ore with aqua regia, to the production of the ingot. Incidentally I also learned how such by-products as iridium, palladium, rhodium, and osmic acid are obtained and handled.

Although several methods have been proposed for the refining of platinum, it appears that the treatment of the ore in the different works is essentially the same; for there is little difference in the manufactured product, whether it come from London, Paris, Hanau, St. Petersburg, or our American refineries.

At the Heræus works the ore is boiled under pressure with dilute aqua regia, whereby the platinum and some of the associated metals pass in solution in the form of chlorides, while the iridosmium and gangue remain undissolved. The chloride solution is evaporated to dryness and heated at 125° C. The residue is then dissolved in water, acidified with hydrochloric acid and precipitated with sal ammoniac. The resulting double chloride, containing only small amounts of other metals, is finally reduced in the manner which I have already described.

The refining of platinum in the dry way, as proposed by Deville and Debray, does not seem to have proved successful, except in special cases and on a smaller scale.

The preparation of chemically pure platinum, *i.e.,* a product which is entirely free from iridium, rhodium, etc., is extremely difficult and tedious, and need not be discussed here.

PROPERTIES OF PLATINUM.

To tell an audience of chemists and students of chemistry about the properties of platinum would be like carrying coals to Newcastle. Some of the physical constants of the metal, it is true, have in recent years been redetermined and revised, but the corrections which have thus been made on the older figures have had no marked influence on the applications of the manufactured product.

What interests us here are those properties, physical and chemical, to which platinum owes its unique position among the useful metals, and its manifold applications in the arts.

The characteristic color and lustre of the metal, though long familiar to the chemist, have only in recent years caught the popular fancy, and their noble ornamental effects are just beginning to be appreciated. The specific gravity of pure platinum is 21.48, but that of the manufactured metal varies considerably, according to the manner in which it has been obtained, and is affected also by the impurities which are present in it. Pure platinum is quite soft, flexible, and extremely malleable and ductile. Like wrought iron, it can be welded at a white heat. Its coefficient of expansion is the same as that of certain kinds of glass. Its melting point is somewhat above 1700° C. (or about 3100° F.), and at still higher temperatures it volatilizes. Moissan has shown that it can be distilled in the electric furnace.

At a red heat it is markedly pervious to hydrogen gas, which is due to the fact that it combines with or absorbs this gas at high temperatures. It forms fusible alloys with many of the metals.

One of its most valuable properties is that it does not tarnish or combine with oxygen, even at high temperatures. In the molten state it does absorb some oxygen, which, however, escapes when the metal solidifies.

As many of us know from sad experience, platinum is readily attacked at higher temperatures by sulphur, phosphorus, arsenic, and silicon, and, under certain conditions, also by carbon.

You also know that platinum is practically proof against the attacks of all acids, except the mixture of hydrochloric and nitric acids. It is, however, dissolved by nitric acid when alloyed with large amounts of silver.

It is also slowly attacked by fused pyrosulphates, and more rapidly by fused nitrates and caustic alkalies.

In the finely divided states of platinum black and sponge, and even as fine wire and thin foil, it produces many remarkable chemical effects, acting as a catalytic agent, especially in the oxidation of many gases and vapors.

Colloidal solutions of platinum have been obtained in a number of ways.

USES OF PLATINUM.

Platinum has not inaptly been called "white gold." Its physical and chemical properties closely resemble those of the yellow metal with which it is generally associated in Nature. But in addition to the many virtues which it shares with gold, platinum has several most valuable properties of its own, and it is chiefly to these that it owes its many uses in science and in the arts.

On account of the great difficulties which had to be overcome in freeing platinum from the other metals with which it occurs in Nature, it was many years after the discovery of the metal before it found any practical applications. The first platinum crucible is said to have been made by Achard. It must have been a very crude affair. The German chemist's process of rendering platinum malleable was improved by the Paris goldsmith Jeannetty, who enjoyed a great reputation for the platinum goods he turned out. I suppose the prototypes of the meter and kilogram were made by his process.

At the beginning of the nineteenth century vessels made of platinum were still so scarce and costly that very few chemists could boast of possessing such apparatus. It was not until the London firm of Johnson & Matthey and the chemist Wollaston developed their method of rendering platinum workable that wire, foil, crucibles, and other articles made of the metal came into more general use. As early as 1809 Johnson & Matthey manufactured a platinum still for the concentration of sulphuric acid which weighed 424 ounces.

It would be difficult to overestimate the effects which the use of platinum apparatus has had on the progress of the sciences and arts. Writing in 1844 Liebig thus characterized the part which platinum plays in the chemist's workshop: "Without platinum it would be quite impossible to carry out a mineral analysis. To render the sample soluble, it must first be fused with suitable reagents. Glass and porcelain, or any other nonmetallic substance of which crucibles are made, would be rapidly destroyed in this operation, while crucibles made of gold or silver would melt at the high temperatures at which the fusions are made. Platinum is cheaper than gold, harder and more resistant than silver, and infusible at the highest temperatures of our furnaces; it combines the valuable properties of gold with those of porcelain. Without the use of platinum the composition of most of the mineral species would still be unknown."

That platinum crucibles were freely used in Liebig's famous laboratory is reflected by a little incident which is told by one of the biographers of the great chemist. It happened that a Paris manufacturer of platinum-ware stopped off at Giessen and visited the laboratory. On being asked whether he wished to see the Director, Professor Liebig, he replied: "M. Liebig? Who is he? I have never heard this name. Show me the way to the excellent M. Aubel. I have sold him many crucibles." Aubel was the *Diener,* or factotum, who had charge of the supplies.

But since the days when there was only one great teaching laboratory in the world, wonderful strides have been made in chemical experimentation and analysis, and the demand for platinum apparatus has grown enormously. In addition to the myriads of crucibles, of various shapes and sizes, chemists now require a host of other platinum utensils, such as dishes and trays, spatulas, tubes, distilling apparatus, electrodes, etc.

As some conspicuous instances of successful experimentation which depended on the use of platinum apparatus, I may mention Moissan's great work on the isolation of fluorine and the proof by Mme. Curie and Mlle. Gleditsch, that the action of radium emanation on copper solutions does not produce any lithium, as Ramsay had supposed.

While platinum is less in evidence in the equipment of physical laboratories, it enters into the construction of a great number of apparatuses and instruments which are employed in the study of heat, electricity, spectroscopy, and the recently-discovered radiations. Much of this apparatus is made of glass, and in providing it with attachments of platinum wire and plates advantage is taken of the fact that platinum and glass expand and contract at the same rate. The coefficient of expansion of platinum is also utilized in the Breguet thermometer.

The application of platinum in the arts is extremely varied, and would be even far more extended, if it were not for the high price and the limited supply of the metal.

The nozzles of the oxyhydrogen and the oxyacetylene blowpipes which are used for cutting iron and steel, as well as for fusing platinum, quartz, and other highly refractory materials, are often made of platinum.

In the manufacture of sulphuric acid, both by the leaden chamber and the contact processes, the metal is used in very large quantities. Since Johnson & Matthey constructed their first platinum still in 1809, this old firm and other manufacturers have furnished a great number of such retorts, and of much greater capacity, to sulphuric acid works in all parts of the world. In the newer contact process, as well as in other chemical manufactures which depend on catalytic action, platinum sponge or platinized asbestos are largely used as the "contact materials." Enormous quantities of platinum also are consumed in the manufacture of electrical appliances, especially of incandescent lamps and the sparking points for internal combustion engines.

But, impressive as are the quantities of platinum required for the purposes I have mentioned, they are equalled, if not exceeded, by those which are absorbed in the manufacture of dental supplies. It is estimated that fully 50 per cent. of the platinum of commerce is consumed in the production of pins, sockets, and other attachments of artificial teeth.

Passing over some minor uses of platinum, as in the construction of standards, the manufacture of surgical instruments, electroplating, china painting, pyrography, etc., it still remains for me to call your attention to another application, which, while not entirely new, has only recently assumed very considerable proportions. I refer to its use in jewelry. For many years parts of jewelry—for instance, of chains, rings, and scarf-pins, etc.—have been made of platinum, on account of the pleasing contrast of its color with the various shades of gold; but it is only in recent years that the beauty of the metal has come to be fully appreciated. At the present time the greater part of the more elaborate settings of diamonds and pearls, as well as a great number of other articles of jewelry, are made of this metal.

A question that naturally suggests itself here is as to whether so precious and noble a metal as platinum is not available for coinage. Aside from its great intrinsic value, its fine and permanent lustre, and its high specific gravity, it readily takes the impression of the die and is harder and tougher than gold and silver. It is probable that in the early years of its discovery in Colombia considerable quantities of platinum passed into the Spanish coin-gold; while later the Spanish Government is said to have issued an order directing its officials to dispose of the objectionable companion of gold by casting it into the sea; and still later the King decreed that the entire output of platinum be delivered to the Crown. It is believed that much of this platinum was used to debase the Spanish coinage.

In 1828, when the Russian Government had accumulated enormous stores of platinum from the Uralian districts, it was decided to convert this surplus into coins, and accordingly three denominations—of 3, 6, and 12 rubles—were minted and put in circulation. This minting of platinum continued until 1845, when it was stopped and the coins were withdrawn from circulation. The reason for this was that, the Russian Government being unable to fix and maintain the price of the metal, large quantities of the coins passed into other countries. Many of them are still preserved in the collections of numismatists. Those shown on the screen are in the collection of the United States Mint in this city; others can be seen in the loan collection in Memorial Hall.[2]

The metal from which these coins were made was not pure platinum. According to Faraday, it contains platinum, 97.0; iridium, 1.2; rhodium, .5; palladium, .25; together with traces of copper and iron.

Just as gold and silver are alloyed with copper (and other metals) to increase their hardness and wearing qualities, so platinum is often alloyed with iridium to increase its resistance to abrasion and the attack of chemicals. Such an alloy goes under the name of "hard" platinum, as distinguished from ordinary platinum. It is more expensive than the latter. Thus most of the vessels used by chemists contain about 2 per cent. of iridium, while much larger proportions of the latter—from 10 to 15 per cent.—are added to the platinum used for the construction of standards of length and weight, for electrodes exposed to severe chemical attack, for sparking plugs, and the points of fountain pens.

For special purposes platinum is sometimes alloyed with

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[2] I am indebted to the kindness of Dr. Jacob B. Eckfeldt, Chief Assayer of the Philadelphia Mint, for obtaining permission to photograph these coins.

Russian platinum coins. From the collection in the Philadelphia Mint.

other metals. An alloy with rhodium is used in certain electric pyrometers; and various alloys with copper, nickel, tungsten, and manganese serve as substitutes for steel in the construction of non-magnetic watches.

Of the compounds of platinum, only a few have found application in analytical chemistry, photography, and physics.

The most important, platinum chloride, or rather chloroplatinic acid, is an invaluable reagent; and barium platinocyanide is used on account of its fluorescence, which converts the ultra-violet rays and X-rays into visible radiations. The shadows made by X-rays are best projected on screens coated with this salt.

SUBSTITUTES FOR PLATINUM.

In view of the great increase in the price of platinum it is but natural that many and persistent attempts have been made to find substitutes for it. In a few instances this has been partially, or even wholly, accomplished; as yet, however, the introduction of such substitutes has had no appreciable effect upon the price of the metal; indeed, it may be said that the demand for platinum has steadily increased in spite of them.

Among the substitutes may be mentioned platinum-clad nickel steel wire, which is beginning to displace the solid wire in incandescent electric lamps; wires of nickel alloys which are used in making the cheaper grades of artificial teeth; asbestos threads which have replaced platinum wire in the Welsbach mantles; and the fused-quartz ware, now so extensively employed in chemical laboratories in the place of platinum utensils.

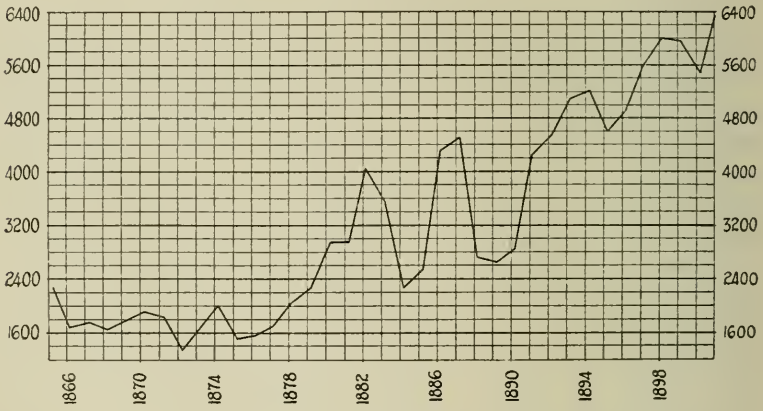
Perchloric acid and sodium cobaltic nitrite are useful in saving platinic chloride in the laboratory.

PRODUCTION.

Statistics on the production of platinum, from the time when it first appeared on the market up to the present, may be found in many publications. An excellent *résumé* up to the year 1901 is given by Dr. B. Neumann in his work "Die Metalle." Our time does not permit of a full discussion of this subject, and I shall content myself, therefore, with a few quotations from this work and some more recent reports, chiefly those published in the "Mineral Resources of the United States."

It is estimated that up to 1778 the entire output of Colombia amounted to 1,943 kilograms; that is, about two tons of the metal. According to Humboldt, the annual production at the time when platinum was discovered in Russia was 545 kilograms. After that the Colombian production gradually decreased. Neumann estimates that up to 1900 Colombia had yielded from 16,000 to 20,000 kilograms. In 1906 the platinum exported from Colombia was 6,813.38 troy ounces (about 200 kilograms).

CHART I.



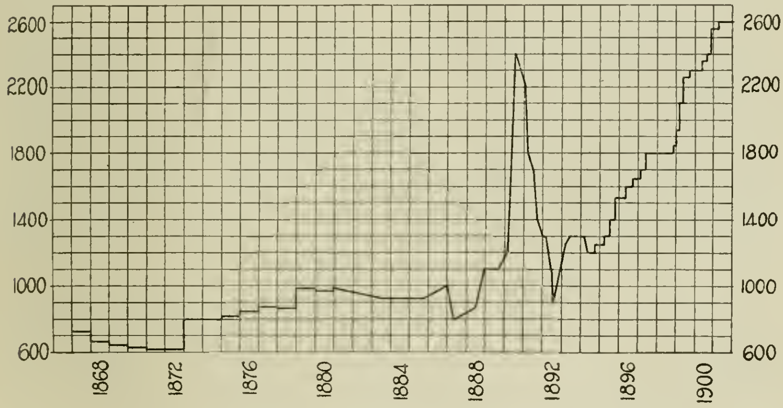
Russian production of platinum, in kilograms, 1865–1901 (after Neumann).

The production of platinum in the Uralian districts began in 1824. From that year until 1845, when the coinage of platinum stopped, it amounted to 30,381 kilograms, of which Nizhni Tagilsk furnished 29,542 kilograms. From that time up to 1864 about 12,000 kilograms were mined in the Urals, and the graphic representation on the screen, borrowed from Neumann, shows the fluctuations of the annual output of Russia, since 1866. It indicates a fairly steady increase since 1875. During the last few years it has been approximately 6,500 kilograms, or somewhat above 200,000 ounces. It should be stated here that the official figures are probably 20 to 25 per cent. below the actual production, owing to the well-known fact that much of the metal is stolen at the mines.

In the United States the production of platinum has been very irregular; it now amounts to several hundred ounces a year: in 1906 a high record was reached with 1,439 ounces, valued at $45,189. Statistics of the production of platinum in British Columbia, Borneo, and New South Wales show great fluctuations, but the totals are quite small, and have probably not reached 100 kilograms in any one year.

The distribution of platinum in the principal industries was estimated by Siebert (writing in 1902) to be as follows: 50 per cent. for dental manufactures; 30 per cent. for chemical and electrochemical industries, and 20 per cent. for electrical manufactures and jewelry. The use of platinum for jewelry has greatly increased since 1902.

CHART II.



Price of platinum, per kilogram, in marks, 1867–1901 (after Neumann).

THE VALUE OF PLATINUM.

During the three or four decades which followed the discovery of platinum in Colombia the valuable properties of the new metal remained unrecognized, and it was then regarded as an undesirable companion of gold. As late as 1778 the Spanish Government ordered all platinum to be sent to the royal treasury, without any compensation. Subsequently, the munificent reward of two dollars per pound was paid by the Crown, but the miners found it more profitable to sell it to English traders, who paid

$12 per pound and then sold it at a much higher price in Europe. Humboldt states that in 1819 the price of the metal on the spot was $8 a pound, while it sold in Paris for nearly four times that amount.

The first platinum found in Russia was sold for $3 a pound. In 1825 the lessee of the Nizhni Tagilsk placers paid $3.50 to $7 a pound, and sold it at $14 to the Imperial Mint.

In 1867 the firm of Johnson, Matthey & Co. paid more than $25 per pound for the crude metal, and in 1877 the price had risen to nearly $40. Our diagram, which is also borrowed from Neumann, shows the fluctuations in the price of platinum, per kilogram, in marks. Dividing the latter by 8, we have roughly the price per pound in dollars.

In 1902 platinum ingots were quoted at $18 per troy ounce; in January, 1906, at $20.50 (about the price of gold, $20.672) per ounce; and during the following months the price gradually advanced to $38 per ounce. While ordinary or soft platinum remained at this figure for some time, hard platinum, containing much iridium, rose to $41 in February, 1907. The prices then declined somewhat, only to rise again, until, at present, ingot platinum is quoted at $45.50.

It may interest you to know how the price of chemical platinum-ware has advanced during the past ten years. The following figures were furnished to me by Messrs. J. Bishop & Co., of Malvern, Pa., through the courtesy of Mr. Geo. D. Feidt:

	1902.	1912.
Crucibles, per gram........	$ .75	$1.70
Foil	.60 to .70	1.55 to 1.65
Wire	.60	1.50
Gauze	.95	1.95
Sponge	.60	1.50

In thus concluding my lecture on platinum I am well aware that I have only lightly touched upon the chemistry and other scientific aspects of the subject. My main object was to show the causes which have operated in advancing the once-despised by-product of the gold placers to the rank of the most precious of the useful metals.

THE DIFFUSE REFLECTING POWER OF VARIOUS SUBSTANCES.[1]

BY

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I. INTRODUCTION.

In all radiometric work involving the measurement of radiant energy in absolute value it is necessary to use an instrument that intercepts or absorbs all the incident radiations; or, if that is impracticable, it is necessary to know the amount that is not absorbed. The instruments used for intercepting and absorbing radiant energy are usually constructed in the form of conical-shaped cavities which are blackened with lampblack, the expectation being that, after successive reflections within the cavity, the amount of energy lost by passing out through the opening is reduced to a negligible value.

A simpler and older form of radiometer is a plane surface covered with an absorbing substance. In this case it is necessary to determine the amount of energy lost by reflection from the surface of the receiver. If the blackened receiving surface is small it may be placed at the centre of curvature of a hemispherical mirror, the radiant energy being admitted through a hole in the centre of the mirror. The receiver being at the centre of curvature of the mirror, any radiations which are diffusively reflected from the receiver will impinge upon the mirror and will return to the receiver. The amount of energy lost by returning upon its path through the opening in the mirror can be determined experimentally.

The most useful substances for absorbing radiant energy are lampblack and platinum black. The present research was undertaken in order to establish methods for the production of standard absorbing surfaces from standard materials, and to determine the completeness of the absorption (*i.e.,* the amount lost by diffuse reflection) of these substances in different regions of the spectrum.

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[1] Extract from a paper to be published in *The Bulletin of the National Bureau of Standards.*

The reverse problem was also presented, of finding a "white" surface, which absorbs the least radiation (high reflection) in the visible and in the adjoining infra-red part of the spectrum, and which has a low reflection in the region of 8 to 9 μ. By this means the surface would absorb but little sunlight; and it would not become heated by the part that is absorbed, owing to re-radiation, which is facilitated by the high emissivity in the region of 8 to 9 μ, where occurs the maximum radiation of substances having a temperature of 20° to 50° C.

Expressed in a more popular way, the interest in the present research was in finding the substances having the extremes in diffuse reflection, *i.e.*, the "whitest" white and the "blackest" black—the former to be used as a paint (which will absorb but little of the sun's rays) to cover a building (*e.g.*, observatory dome) which is to contain instruments that are sensitive to changes in temperature; the latter to be used as the absorbing surface of a radiometer which is located within this building.

While it is beyond the scope of the present investigation to discuss the theoretical aspects of this subject, it is of interest to notice the extraordinary, and apparently inconsistent, ways in which these extremes in diffuse reflection are produced. In optically transparent media (insulators), such as glass, the absorption coefficient and the refractive index are low; and the amount reflected regularly ("specular reflection") is of the order of 4 to 5 per cent. On the other hand, in the metals (electrical conductors), such as platinum, the absorption coefficient and the refractive index are high; and the amount reflected regularly is of the order of 80 to 100 per cent., depending upon the wave-length. On first consideration it therefore seems somewhat contrary to the natural order of things to produce a high (90 per cent.) reflecting (diffuse reflection) surface from the former, and an extremely low (2 per cent.) reflecting surface from the latter, by merely changing the size of the grains which form the reflecting layer.

The high reflecting power of fine particles of transparent substances (insulators) is easily explained as the result of successive internal reflections and refractions of the light which penetrates their surfaces. If the particles are small the chances are that total reflection will occur before the rays have penetrated to a great depth, and (there being practically no absorption) the rays are reflected with almost the same intensity as obtained in the incident radiations.

When the reflecting particles have a high absorptivity, but have a low refractive index, which is true of lampblack, the same optical conditions obtain as in the more transparent particles, the only difference being that at each internal reflection the rays are further absorbed so that the intensity of the reflected rays is quickly reduced to a small value in comparison with the incident rays. The blackest deposits of soot are made by holding a metal plate in an acetylene flame, which forms an extremely fine-grained surface. Such a deposit, viewed at grazing emergence, has the appearance of a highly-polished mirror of fairly high reflecting power.

The effect of grain size upon the amount of energy (diffusively) reflected from the surface is well illustrated in the present paper, which gives the reflecting power of a cleavage surface and of a coarsely-ground surface of white marble. The cleavage piece (about 1 cm. thick) was well illuminated throughout the interior to the rear surface, owing to the large size of the individual crystals, some of which had cleavage faces 0.2 to 0.3 mm. diameter.

The low reflecting power obtained by reducing the size of metallic particles (*e.g.,* platinum black) to the dimensions of light waves is not so easily explained. If the black mass is a coagulation of colloidal metal its optical properties (refractive index, etc.) are the same as that of the metal.[2]

Evidently it is not a question of roughness of surface, for a deposit of platinum black (upon a strip of platinum) when heated to a low red heat sinters into a white mass. By eliminating the high reflecting power, platinum could become black by assuming a structure of fine particles, which consist of cavities with small openings. Such a condition would be realized if the material had the structure of a bundle of polished needles,[3] turned with their points toward the light. By multiple reflection the rays will travel down into the interstices between the needles (particles forming the spongy mass), and practically none will escape by reflection back upon their path. It is conceivable that by electrolysis the platinum black might be deposited in isolated points with relatively large spaces intervening, and that, as the electrolysis continues, these points increase in height and diameter, thus forming a porous, needle-shaped structure. This would increase the absorption of electrolytically-deposited platinum black (as observed), but it does not fully explain the physical condition of the chemically-precipitated material, unless we assume that the latter, which is colloidal, was built up in a similar manner by coagulation.

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[2] Spence, *Phys. Rev.,* 23, p. 233, 1909.

[3] Kurlbaum, *Ann. der Phys.* (3), 67, p. 855, 1899.

Wood, Physical Optics, New Edition, p. 449, "Absorption by Porous Surfaces."

A more plausible explanation, alluded to by Kurlbaum, is based upon the depth of penetration of the rays into the metal and the thickness of the reflecting layer. In order to obtain reflection, a definite thickness of metal is required, which thickness is a function of the wave-length of the incident light. Hagen and Rubens[4] determined the reflecting power of gold with thickness on the assumption that the layer is homogeneous—*i.e.,* not formed of discrete particles with intervening spaces of glass. They found that for a layer 0.01 μ in thickness the amount of light reflected was about 10 per cent. of the total reflecting power for that wave-length. The maximum thickness required for complete reflection of all wave-lengths was about 0.08 μ. The smallest particle of colloidal material (*e.g.,* gold) observable in a microscope is of the order of 0.01 μ.[5] It is conceivable that there are colloidal particles which are still smaller, and that platinum black is made up of aggregations of these invisible particles. In this case it is conceivable that if the thickness of the particle is less than the minimum thickness required in the transition layer to obtain reflection, then the rays will pass through the particle, diminished in intensity by the amount absorbed in the particle. This is the (somewhat elaborated) view taken by Kurlbaum (*l.c.*), who based his line of argument upon Stark's[6] investigations of the physical properties of soot. In a deposit of soot, Stark considered the air a turbid medium, containing the particles of soot.

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[4] Hagen and Rubens, *Ann. der Phys.* (4), 8, p. 432, 1902.

[5] Burton, *Phil. Mag.,* 2, p. 425, 1906.
Spence, *Phys. Rev.,* 23, p. 233, 1909.

[6] Stark, *Ann. der Phys.* (3), 62, p. 353, 1897.

Owing to the high absorption coefficient of metals the rays should therefore be completely absorbed in a thinner layer than is required in lampblack. Kurlbaum found that about 3.5 times as much (by weight) platinum black was required to produce the same absorption as in soot. Evidently not all of the individual particles of platinum black are of the minimum thickness required to avoid reflection, or the material has some property as yet unknown. This is inferred on the assumption that the density and the thickness of the layer of these two materials is the same in the experiment, which was not the case. Evidently further investigations are necessary to decide these questions.

In the foregoing paragraphs we have noticed the most probable causes which are instrumental in producing these two extremes in diffuse reflection. In view of the fact that many of the insulators (optically transparent media, for the visible spectrum) have two types of absorption (reflection) bands in the infra-red, which sometimes fall within the spectral regions examined in the present investigation, it is important to notice the distinction between these two types of bands. For example, a plate of quartz is transparent to the visible spectrum, has absorption bands in the region of 4 μ and a band of metallic reflection in the region of 9 μ. The apparently anomalous condition of a high (diffuse) reflection of the powder, in the visible and at 8.8 μ, and a low reflection at 4.4 μ, is therefore easily explained. For in the region of 4.4 μ the surface permits the formation of "body color," as is true of pigments.[7] In the region of 8.8 μ the high reflection in powdered quartz is owing to the coarseness of the grains. If the grains were as fine as those of platinum black, one would expect the reflecting power in this spectral region to be as low as obtains in platinum black. Similar conditions are to be observed in some of the pigments, (*e.g.*, litharge, yttrium oxide, and chromium oxide).

II. SUMMARY OF PREVIOUS INVESTIGATIONS.

Three methods have been used in determining the amount of energy lost by diffuse reflection from rough surfaces. The first method is based upon the assumption that the diffusion follows the cosine law. The amount of incident energy is measured; also the amount of energy reflected at a given angle from the normal. By integration the total amount is obtained that is lost by diffuse reflection. This method was used by Angström.[8] He used a surface bolometer at an angle of 40°, and found that for a thickly-sooted platinum black surface the reflecting power varied from 0.82 per cent. to 1.25 per cent., being apparently larger for the short wave-lengths. Practically the same method was used by Hutchins.[9] With a radiomicrometer he investigated the cosine law of diffuse reflection of various substances. He found that the diffusion from rough surfaces of such substances as magnesium oxide and plaster departed an appreciable amount from the cosine law for large angles, while for paper this departure was very marked for angles between 20° and 60°. By integration he found the total amount of energy lost by diffusion.

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[7] See Wood's "Physical Optics," New Edition, pp. 441 and 439, "Body Color and Surface Color."

For a white surface "plaster," using sunlight as a source of energy, the integrated value for the reflecting power (the albedo) was 92.7, for paper it was 82.6, and for a green leaf it was 30.2, which values are in fair agreement with the results of the present research.

Another method for obtaining the diffuse reflecting (the absorbing) power is to compare the emission of a heated surface with the emission of a black body which is at the same temperature. This method was used by Crova and Compan.[10] They found that the loss by reflection from the soot of a candle flame varied from 0.68 to 1.25 per cent.; and for a layer of the same washed with alcohol the loss was 3.17 per cent. Kurlbaum[11] used this method to find the absorption (emission) of different thicknesses of electrolytically-deposited platinum black and of soot. For soot the maximum emission of 94.5 per cent. was attained in a deposit containing about 30 mg. per dm.^{2}; but using a thicker deposit of about 100 mg. per dm.^{2}, the emission was only about 88 per cent. of a black body. In platinum black the emission was only about 30 per cent. for a deposit weighing

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[8] Angström, Öfversight Af. K. Vetensk. Akad. Förhandlinger, Stodkholm, 55 (No. 5), p. 283, 1898.

[9] Hutchins, *Amer. Jour. Sci.*, 6, p. 373, 1898.

[10] Crova and Compan, *Compt. Rend.*, 126, p. 707, 1898.

[11] Kurlbaum, *Ann. der Phys.* (3), 67, p. 846, 1899.

30 mg. per dm.^{2}. The maximum emission of 96.8 per cent. was attained in deposits weighing about 200 mg. per dm.^{2}, which value remained constant for deposits weighing 300 mg. per dm.^{2}.

He recommended that, for measuring radiations of wavelengths up to 8 μ, it is sufficient to deposit the platinum black for 3 minutes. According to the present method of investigation, in which the platinum black was produced by the same formula as used by Kurlbaum, the deposition of platinum black should be continued for 5 to 6 minutes.

The main objection to this method is that it gives values for the complete spectrum.

A third method is to place the reflecting substance and a radiometer at the conjugate foci of a hemispherical mirror. The incident radiation is introduced upon the reflecting substance by passing through a hole in the centre of the mirror. This method is the easiest to employ; but it requires the determination of several correction factors, which, however, are constant quantities in the investigation. These corrections are (1) the amount of radiation which escapes through the opening in the mirror, and (2) the amount of diffuse radiation which, in its course from the reflecting substance to the radiometer, is absorbed by the silver mirror.

Using this method, Royds [12] carried out a series of measurements under the direction of Paschen. In view of the fact that the present research was well under way when the results of Royds were published, and that the methods differ only in minor but vital points (but that the results are at considerable variance), it is of interest to notice this work in some detail.

Royds used a hemispherical mirror of brass, 5 cm. in diameter. The Rubens thermopile and the blackened strip were placed side by side in the focus of the mirror, and the incident energy (the image of an illuminated slit) was projected on either the strip or the thermopile by means of an external concave mirror. The thermopile did not present a completely opaque surface to the incident radiations, and hence a great amount of the available energy could not be utilized. Moreover, the slit image, after reflection from the diffusing surface, may not be very sharp and it may not be uniformly illuminated. This is very marked in the transparent "white" substances, in which much of the light is reflected at considerable distance below the surface, so that the observations must be made upon the assumption that the distribution of the radiation (the "illumination") is the same in the slit image before and after reflection from the diffusing surface. This uniformity of illumination is probably of minor importance for black surfaces; but it is of considerable importance with white surfaces, which may reflect as high as 90 per cent. of the incident energy. Royds makes no mention of having tested his outfit with a white diffusing surface (*e.g.*, magnesium carbonate) which gives a surprising amount of information in regard to the adjustments, the distortion and illumination in the slit image, etc.

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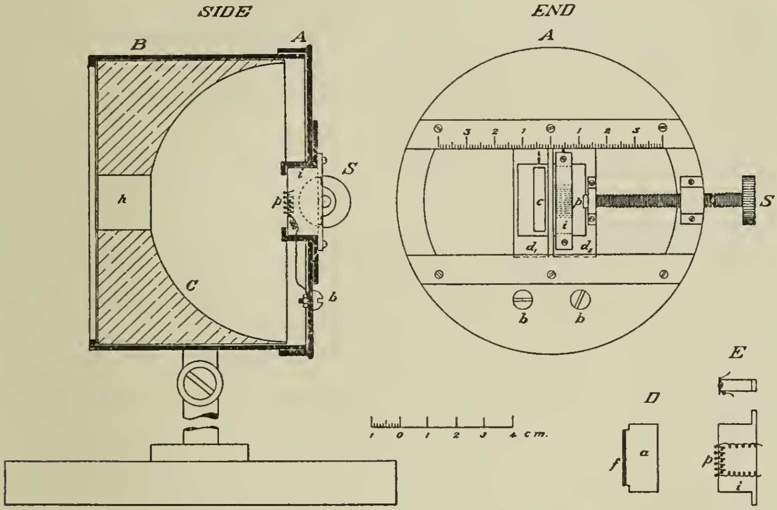
[12] Royds, *Phil. Mag.*, 21, p. 167, 1911.
Phys. Zeitsch., 11, p. 316, 1910.

The thermopile and the reflecting surface were stationary, and the image of the illuminated slit was projected upon either one by means of an external concave mirror. This did not permit the use of a cone of rays which filled the opening in the hemispherical mirror. This resulted in a further reduction of the available incident energy, so that in order to be able to measure the small amount of energy which is reflected from lampblack a very sensitive ($i = 0.7 \times 10^{-10}$ ampère) galvanometer had to be employed. As a result, he had to apply corrections for diffuse radiation from the incident image, and for energy radiated from the black surfaces as a result of warming from exposure to the incident radiation. No corrections were made for absorption by the mirror, nor for the opening in the mirror, which correction, he says, could not be estimated. The various corrections to his observations were such that his "apparent" values are two to three times the "true" values. His "apparent" values are usually in fair agreement with results obtained in the present paper.

III. APPARATUS AND METHODS.

In designing the present apparatus, the attempt was made to utilize the maximum amount of the available energy. This permitted the employment of a galvanometer of low sensitivity, which eliminated such corrections as necessarily result when using a very sensitive radiometer. For example, the correction, used by Royds for the diffuse energy falling upon the thermopile caused by the reflection from air particles when the incident radiation is directed upon the lampblack, was *nil* in the present investigation. The utilization of a large amount of the available incident energy resulted from: (1) the employment of a large hemispherical mirror which permitted the use of a large incident slit image and a large reflecting surface without distortion; (2) the use of a radiometer which intercepted the whole slit image;

FIG. 1.



(3) the use of a beam of radiations which filled the opening in the hemispherical mirror, which was made possible by shifting the thermopile and the diffusing surface, instead of shifting the slit image, as was done by Royds. The main defect in moving the thermopile from its position at the conjugate focus of the reflecting surface (*p*, Fig. 1 A) to the position, *c*, occupied by the reflecting surface, which is necessary in order to determine the intensity of the incident radiation, is the shift of the galvanometer reading owing to differences in emissivity and in temperature in the two positions. This is not marked, however, at the low galvanometer sensitivities used in the work.

The apparatus resulting from the foregoing considerations proved far more sensitive than was expected, so that for all spectral regions investigated (excepting at 24 μ) the galvanometer,[13] of 5.09 ohms resistance, was used on a complete period of 2 to 3 seconds and a sensitivity of about 1×10^{-9} ampère. For the spectral region of 24 μ the complete period of the galvanometer was from 4 to 5 seconds, the corresponding sensitivity being about 4×10^{-10} ampère.

The ability to use a short-period galvanometer afforded a great saving in time. In fact, the time was consumed mainly in waiting for the optical system to come to temperature equilibrium after mounting a specimen in the hemispherical mirror. This, however, was not a serious matter, owing to the low radiation sensitivity required in the work.

(1) *The Thermopile.*—The bismuth and silver [13] used consisted of 22 junctions mounted in a space 10.5 mm. long, as shown at *p,* Fig. 1 A, and Fig. 1 E. Its width was 5 mm., and its resistance was 10.8 ohms. The individual junctions were made of bismuth wire 0.1 mm. in diameter and silver wire 0.0513 mm. diameter, mounted upon an ivory support, *i,* as shown in Fig. 1 E. The wires leading to the galvanometer were attached to the binding posts *b, b,* Fig. 1. The thermopile was blackened with a mixture of lampblack and platinum black, then smoked with soot from a sperm candle. It was covered with a sheet of glass 0.095 mm. in thickness for the spectral region to 0.95 μ; and with a plate of clear rock salt 0.8 mm. in thickness for the longer wave-lengths. The use of a receiver that intercepted the whole slit image eliminated the question of distortion and uniformity of illumination. In the incident slit image the rays are received in practically a normal direction upon the thermopile. In the slit image, formed from the rays reflected from the diffusing surface, the rays fall upon the thermopile at all angles of incidence. The only assumption which is made is that the difference in the loss by reflection from the thermopile and the window is negligible in these two measurements.

(2) *The Hemispherical Mirror.*—The diameter of the hemispherical mirror, which was made of glass, was 10 cm., and the opening for admitting radiation upon the thermopile was 10 by 20 mm.

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[13] *Bulletin Bureau of Standards,* 9, p. 7, 1912.
Journal Franklin Institute, Dec., 1911.

The arrangement of the mirror in the mounting is shown in Fig. 1 B. The support for the thermopile and the substance to be investigated was mounted upon a movable stage, *d, S,* which in turn was mounted upon a brass plate which was provided with a wide flange (Fig. 1 A). By slightly tilting this brass plate, *A,* upon the support, *B,* it was possible to focus the slit image of the radiations reflected from the diffusing surface, *f,* Fig. 1 D, upon the thermopile, *p.* This adjustment of focus was necessary for specimens which did not fit nicely in the place occupied by the brass block, *a,* upon which the substances, *f,* were usually mounted.

The distance (6 to 7 mm.) between the incident slit image, upon the surface, *c,* and its reflected image upon the thermopile (*p,* Fig. 1 A) was made as small as possible in comparison with the size of the hemispherical mirror. Previous tests with a Nernst glower 10 mm. long showed no distortion of the image of the glower for a displacement of 1.2 cm. from the axis of the mirror. However, in the slit image of the light reflected from the diffusing surface the illumination did not appear so uniform, and there appeared to be more aberration at the ends of the slit image. This was especially marked in a cleavage piece of marble, from which the reflected slit image was surrounded with a hazy illumination. A piece of white cardboard with an opening 5 by 10 mm. was placed over the thermopile. This facilitated in focusing, and in determining that all the diffusely reflected light fell upon the thermopile.

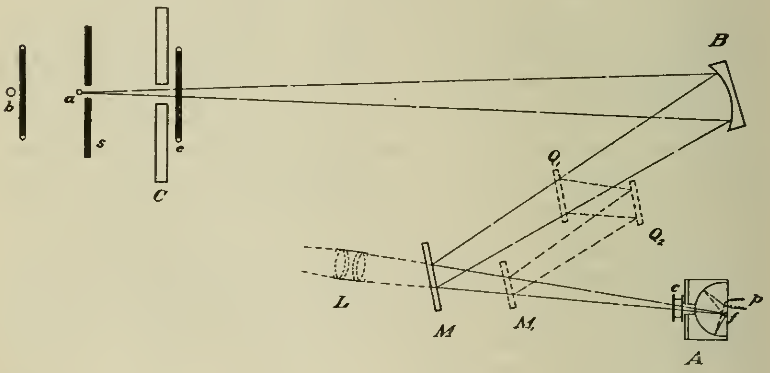
These adjustments were made with a white diffusing surface (of Al_2O_3 or $PbCO_3$) of the same thickness as the lampblack surfaces, which, owing to its high reflecting power, produced a bright slit image. In this manner the effect of change in focus upon the amount of radiation falling upon the thermopile was investigated.

(3) *The Optical System.*—The arrangement of the optical parts of the auxiliary apparatus is shown in Fig. 2, which shows the hemispherical mirror, *A,* containing the reflecting substance, *f,* and the thermopile, *p.* The cylindrical acetylene flame was at *a,* and the Bunsen flame, or Welsbach mantle, was at *b.* The shutters, *d* and *e,* were made of thin sheet aluminum (10 by 15 cm.), with an intervening layer of asbestos about 3 mm. in thickness. They were bright on the front side, and painted black

on the side toward the thermopile. A large, water-cooled diaphragm, with an opening 5 cm. in diameter, was placed at *C*. A flame placed back of a large plate of sheet iron, with a slit, *s*, represented the source of energy. An image of this slit was projected into the hemispherical mirror by means of a large concave mirror, *B* (17 cm. diameter, 100 cm. focal length), or by means of a triple achromatic lens, *L*, having a diameter of 6 cm. and a focal length of 18 cm. In the latter arrangement, which was used in the first observations at 0.6 μ, the slit, *s*, and flame, *a*, were, of course, placed on the axis of the lens, *L*.

The arrangement of the two flames, *a* and *b*, the concave mirror, *B*, and the plane, silver on glass, mirror, *M* (with or without an absorption cell, *c*), as shown in Fig. 2, permitted the measurement of the radiations at 0.65, 0.95, and 4.4 μ, in succession, before changing a specimen. For isolating the radiations at 8.8 μ two quartz plates, 5 mm. in thickness (ground and blackened on the rear side), and the silver mirror, *M′*, were placed as shown at Q_1 and Q_2. Two fluorite plates were placed at Q_1 and Q_2, respectively, for isolating the radiations at 24 μ. The proper positions of these mirrors were obtained by focusing with silver on glass mirrors at Q_1 and Q_2 respectively.

FIG. 2.



The beam of light did not entirely fill the opening, *h*, in the hemispherical mirror, so that by slightly turning the mirror, *B*, about a vertical axis it was possible to change the angle of incidence of the radiations, and project them upon different parts of the reflecting surface, *f*, which usually was about 6 mm. wide, and from 12 to 20 mm. in length.

The material to be examined was usually melted upon a brass block (*a*, Fig. 1 D), which was 25 by 6 by 10 mm., which was inserted in the opening, *c*, in the stage, d_1, Fig. 1.

The arrangement of the shutter, *d*, and the gas mantle, *b*, at a distance of about 15 cm. from the slit, *s*, Fig. 2, prevented the latter from becoming warm and radiating upon the thermopile, which would happen when the water cell, *c*, was not in place. When the gas mantle or the Bunsen flame was used (for radiations at and beyond 4.4 μ), the acetylene was, of course, extinguished, the shutter, *e*, was kept raised, and the absorption cell, *c*, was removed.

When using the triple achromatic lens for projecting the slit image, the size of the opening in the sheet of metal, *s*, which formed this slit, was 1.5 by 7.5 mm., and the image was practically the same size. Owing to the large angle of incidence there was some astigmatism in the image produced by the concave mirror. The slit was therefore reduced to 7 by 2 mm., and finally to 7 by 1.5 mm. In all cases the image of the slit at *f* was about 8 by 2 mm., hence there was no danger of the radiations falling outside of the thermopile, especially after reflection at *f*, and refocusing at *p*, Fig. 2, when the slit image was not very sharp.

The method of determining the reflecting power consisted in observing the galvanometer deflection when the radiations were projected upon the specimen at *f*, and after reflection therefrom were focused upon the thermopile at *p*; then, moving the stage, *S*, Fig. 1, until the thermopile occupied the position of *f*, in observing the galvanometer deflection for the direct slit image. The ratio of the reflected radiations to the direct radiations (in galvanometer deflections) gives the reflecting power. The observations were duplicated for most of the substances. This is especially true for the radiations at 0.65 μ, where the triple achromatic lens and also the concave mirror arrangement were used for projecting an image of the slit upon the substance; also for the radiations at 0.95 and 4.4 μ, using the concave mirror for projecting the slit image. In the final work many of the original observations were repeated at 0.95 μ and 4.4 μ (using the two flames and shutters, as already described) before removing the specimen. Throughout the work the various specimens were kept covered to prevent the deposition of dust.

(4) *Regions of the Spectrum Examined.*—The reflecting power of various substances was found for the following regions of the spectrum.

(1) That part of the radiation of an acetylene (cylindrical) flame which is transmitted through a 1 per cent. solution of cupric chloride,[14] 2.5 cm. in thickness. Such a solution is opaque to all radiations lying beyond 0.7 μ. The energy curve of this transmitted radiation does not differ markedly from the solar energy curve. The maximum of the transmitted energy lies at 0.6 μ.

(2) That part of the radiation from an acetylene flame which is transmitted by a 1 per cent. solution of cupric chloride 2.5 cm. in thickness and a plate of green glass 2.5 mm. in thickness. The transmitted radiation is fairly monochromatic, the maximum being at 0.54 μ.

(3) The radiation of an acetylene flame which is transmitted through a 2 cm. layer of water. The water cell transmits uniformly all the visible and part of the infra-red to 1.4 μ. The maximum of the energy curve of the transmitted radiation lies at 0.95 μ. By using a plate of red glass 2.15 mm. in thickness, as indicated in the tabulated data, the radiations are more homogeneous, extending from 0.67 μ to 1.4 μ.

(4) The radiation from a Bunsen flame, which consists of a small emission band at 2.7 μ and a very strong band at 4.4 μ. About 90 per cent. of the energy emitted by a Bunsen flame lies at 4.4 μ.

The purity of the maximum emission was tested with a thick plate of glass which is opaque to radiation lying beyond 3.5 μ. A sheet of plate glass 8 mm. in thickness transmitted 5.8 per cent., and a sheet 15 mm. in thickness transmitted 3.7 per cent. of the radiation from the flame. From this it appears that the homogeneity of the Bunsen flame radiation at 4.4 μ is not seriously affected by the weak radiations at 1.9, 2.7, and 5.3 μ.

(5) The residual rays from quartz. The source of energy was the radiation from a Welsbach mantle which was reflected from two surfaces of quartz, which has two intense bands of

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[14] *Bulletin Bureau of Standards*, 7, p. 619, 1911; also 1912.

selective reflection, at 8.50 and 9.05 μ, respectively. The mean of the energy curve is at 8.8 μ. The maximum of this radiation was very homogeneous, only 0.43 per cent. of the total radiation being transmitted by a glass plate 1.5 mm. in thickness. The glass plate transmitted radiations to 4.5 μ, beyond which point, up to 8 μ, the reflecting power of quartz is extremely low; and throughout this region of the spectrum the radiation from the gas mantle is very weak.

(6) The residual rays from fluorite. The source of energy was an incandescent gas mantle, reflected from two plates of fluorite. The maximum of the energy curve was fairly homogeneous, 1.5 per cent. being transmitted by glass (opaque beyond 4.5 μ) and 7.8 per cent. being transmitted by a plate of fluorite 1.5 mm. in thickness, which is opaque beyond 10 μ. The homogeneity could have been increased by adding another reflecting surface of fluorite; but it would have been at a sacrifice of the total energy available. Most of the black reflecting surfaces examined increase in reflecting power with wave-length. Hence, it is to be inferred that the observed values would be a trifle higher than here observed if the radiation had been more homogeneous. This is of minor importance, owing to the variation in reflecting power of samples of the same substances. The thermopile was covered with a plate of rock salt, 0.8 mm. in thickness, which is opaque to radiations beyond 30 μ; hence, the maximum of the residual rays is shifted from its true position to about 24 μ.

(5) *Corrections to Observations.*—A part of the energy reflected from the substance under examination escapes through the opening which admits the radiations into the mirror. The amount of energy thus lost was determined experimentally by covering, temporarily, a part of the silvered surface adjoining the opening by means of a thin sheet of aluminum blackened in an acetylene flame. The aluminum sheet was bent to fit the curvature of the mirror, and the area of the blackened surface was 10 by 20 mm. When not in use this blackened surface was withdrawn through the opening in the hemisphere. The experiment consisted in noting the amount of energy (in galvanometer deflections) reflected from a layer of lead carbonate *with* and *without* the blackened surface in place within the hemisphere. The ratio of the galvanometer deflections in four

complete series of observations varied from 97.1 to 97.5 per cent., with a mean value of 97.3 per cent. On the assumption that, in the region occupied by the black surface, the illumination differs by a negligible amount from the value for the centre of the mirror, the amount of energy lost by escaping through the opening is about 2.7 per cent. of the total energy diffusely reflected within the hemisphere.

TABLE I.

REFLECTING POWER OF LAMPBLACK.

Wave-length. λ max.	.54μ	.60μ	.95μ	.95μ (red glass)	4.4μ	8.8μ	24.μ
	%	%	%	%	%	%	%
Silver	93.2	89.9	93.4	94.6	98.0	98.0	98.5
Aluminum		68.5			92.3		
Correction factor	1.102	1.143	1.100	1.086	1.049	1.049	1.043
Lampblack Paint		2.94			3.24		
		3.02			2.29		
		3.58			3.60	Alcohol + shellac.	
		3.72			4.86		
		3.10	3.38	3.36	3.34	3.75	4.4
Paraffin candle (hot)			0.97				
(Cold soot)		1.07 1.43					
Rosin			1.26		1.31		
					.85	1.07	2.8
Sperm candle			.91		.67	1.44	3.9
			1.02		.93	1.27	4.1
			1.25		1.03		
			1.07		.77	1.28	
			1.01		1.36	1.23	
					1.28	.87	
Camphor (Paint)			1.34		1.38	1.46	
			1.30		.95	1.65	5.7
			1.36		1.15		
			2.80		3.24		
Acetylene			.59				
			.82		.92	1.12	3.0
			.64		.71	1.24	
			.54		.81		
			.42		.71		
(Cold deposit)			.86				
(No air)			1.33				

A further correction is necessary for the absorption of the diffuse radiations by the silvered surface of the hemispherical mirror. This correction, which depends upon the spectral region observed, was determined by placing a newly silvered plane mirror in the place occupied by the diffusing surface, *f*, Fig. 2, and at *c*, Fig. 1 A. This plane mirror was placed at the proper angle to reflect all the incident energy upon the interior of the hemispherical mirror and from thence upon the thermopile. The ratio of the galvanometer deflection for the energy reflected from the silvered surface, to the deflection for the energy falling directly upon the thermopile, gave the reflecting power of the two silver surfaces, and the square root gave the value sought for a single reflecting surface. These values of the reflecting power, determined by this method, are in excellent agreement with the values obtained by the methods previously employed by other observers. The values of the reflecting power of silver, for the spectral regions employed, are given in Table I. In this same table are given the complete correction factors with which the observed (the "apparent") reflecting power of the various substances was multiplied in order to obtain the "true" (the absolute) values recorded in these tables. These factors are the reciprocals of the products obtained by multiplying the reflecting power of silver by the per cent. of diffuse energy (97.3) which is intercepted by the hemispherical. The silvered surface, being well protected, does not tarnish, so that these correction factors are constant for the investigation.

The corrections used by Royds, viz., (1) the correction for extra radiation falling upon the thermopile, as the result of scattering by air and dust particles when the incident radiation was projected upon the diffusing surface, and (2) the correction for re-radiation upon the thermopile, as a result of warming of the diffusing surface by the incident radiation projected upon it, were *nil* in all cases, except when very thick (0.3 to 0.4 mm.) layers of lampblack were examined. The thick lampblack surfaces seemed to become heated when they appeared to radiate upon the thermopile. To the eye they were just as black as thin deposits of (acetylene) soot. Nevertheless, they apparently reflected from 2.5 to 2.8 per cent. at 0.95 μ and 4.4 μ, and 8 to 12 per cent. at 8.8 μ. A thin deposit of soot which appeared equally black, and examined at the same time, would reflect less than 1 per cent. The lampblack paints also reflected about 3 per cent., and they appeared very much lighter (reflected more of the incident radiation upon the thermopile, as could be observed visually) than the soot deposits. To prevent radiations of the heated thick films of soot from falling upon the thermopile, a thin (0.09 mm.) sheet of glass was placed over (and about 1 mm. from the surface of) the deposit of soot. The reflecting power of the thick layer at 0.95 μ was then reduced from 2.7 per cent. to 1.08 per cent., which is about as low a value as observed on a thinner film in which the conductivity to the brass block was effective. It was evident that the high reflection was caused by re-radiation, and no attempt was made to examine very thick films such as used by Royds. The thickness of the deposits of soot was of the order of 0.1 mm., which by experiment was found sufficient to absorb the maximum amount of radiation. The presence of stray radiations was also

TABLE II.

REFLECTING POWER OF PLATINUM BLACK.

Wave-length. λ max.	.60μ	.95μ	.95μ (red glass)	4.4μ	8.8μ	24.μ
	%	%	%	%	%	%
Chemically precipitated paint	2.01	2.92		6.00		
		2.43	2.50			
			2.53	5.76	8.67	12.1
Platinum black and lampblack paint	2.77	2.70	2.84	4.02 3.94	6.44	8.2
Platinum black and soot	1.46	1.38				
Electrolytic:						
No. 4		1.22		8.8	13.2	
No. 5		9.8		2.64	4.63	
"		1.16		2.68		
No. 14, 1 minute					25 to 30	
No. 13, 2 minutes					11.3	
No. 9, 3 minutes					5.9	
No. 10, 3 minutes		.99		1.72	3.66	7.5
No. 11, 4 minutes				1.54	2.40	4.4
" "		1.16		1.59		
No. 12, 5 minutes		1.12		1.50	1.84	3.9
No. 16, 5 minutes		.85		1.48	2.71	
No. 15, 6 minutes		1.01		1.51	2.23	3.4
No. 18, 6 minutes				1.33	1.78	
" "		1.08		1.35		
No. 19, 6 minutes					2.13	
No. 19 and soot				.93	1.27	4.1
" "		1.25		.99		
No. 17, 7 minutes		.98		1.44	1.82	3.3
No. 20, 7 minutes				1.29	1.88	2.9
" "		.97		1.31		

tested. To this end the reflecting surface (brass block) was removed from the carrier, *d,* Fig. 1, and the radiations coming through the opening, *h,* in the hemispherical mirror were permitted to pass out through *c* to the rear of the apparatus and fall upon a piece of black velvet. This test was applied at various times in the different spectral regions used and at various galvanometer sensitivities, but no deflection (as large as 0.1 mm.) could be observed which was caused by radiations scattered by air and dust particles. The galvanometer could be read to 0.1 mm. The smallest deflections, observed by reflection from the blackest surfaces, were from 8 to 10 mm., and usually they were much larger. Hence, if there had been corrections such as observed by Royds, they could not have escaped notice. As mentioned elsewhere, the apparatus was designed so as to require a low radiation sensitivity which eliminated these corrections, and the accuracy which one could easily attain was 1 part in 200 to 400. Evidently, from the nature of the material, it would have been illusory to attempt a higher accuracy. As an illustration of the accuracy attainable on a low reflecting power substance, the value for platinum black (No. 16, Table II) may be cited. Two determinations on different days gave respectively 2.71 and 2.75 per cent. for the reflecting power.

IV. REFLECTING POWER OF LAMPBLACK.

The experimental results obtained in this research may be briefly portrayed by means of tabulated data and by brief comments relating thereto. As found by others, all sorts of lampblack (soot) surfaces can be prepared, differing in reflecting power, for the same flame and for different flames. The most permanent coatings are, of course, layers of paint made by mixing lampblack with turpentine, or, if the latter dries too slowly, with turpentine and alcohol. A weak alcoholic solution of shellac gives a much more grayish appearance to lampblack, as shown by the highest values obtained in Table I. But the reflecting power of the paint is so high that it is a question whether it might not be better practice to resmoke radiometers when the soot comes off.

Owing to the fact that many of the soot deposits became soiled before they could be examined in another spectral region, and also to the fact that in any given spectral region various deposits of soot were examined, when they were removed from the brass blocks to be replaced by others, but few of the same deposits were examined in more than two or three parts of the spectrum. Hence (for clearness), Table I differs from the other tables in that the observations of reflecting power upon the same film, in different spectral regions, are joined by dotted lines. The additional observations in any spectral region, *e.g.,* sperm candle, at 8.8 μ, are recorded without any special reference to the other observations.

Various experiments were performed on lampblack paints prepared from commercial lampblack. The best (purest) material gave reflecting power varying from 2.9 to 3.1 per cent. at 0.60 μ. This is in agreement with results obtained by depositing soot from burning camphor in a "watch crystal" and working it into a smooth paint with turpentine. As shown in Table I, the reflecting power of lampblack paint is fairly uniform in the region of 4 to 8 μ, and a fair correction factor for diffuse reflection from a radiometer is from 3.3 to 3.5 per cent.

Finely-ground boneblack, although having a very brownish color, becomes quite black ($R =$ about 1.5 per cent.) when the turpentine has not thoroughly dried. From this it would appear that if the proper vehicle could be found it might be a much darker paint than ordinary matte lampblack paint.

The deposits of soot from the different flames were "hot" when the brass block was drawn through the flame or "cold" when the flame was cooled by a sheet-iron funnel, with an opening 1 by 10 mm. at the top, through which the smoke issued, and over which the brass block was held. The cold deposits usually had a higher reflecting power than the hot deposits. As already mentioned, layers 0.05 to 0.1 mm. in thickness usually produced a maximum absorption. Thicker films produced higher values for the reflecting power, owing to heating of the surface as the result of lack of conduction to the brass block, which then radiated upon the thermopile.

Some of the samples of soot appeared to have a slightly higher reflecting power in the visible than in the infra-red, as was shown by repeated measurements upon the same film. In the case of the deposit of soot (from a sperm candle) upon the layer of platinum black, No. 19, Table II, the reflecting power is considerably higher at 0.95 μ than at 4.4 μ. Whether this is owing to the structure of the material, depth of penetration (which is a function of the wave-length), and consequent variation in conductivity, is unknown. It does not appear unreasonable to suppose that, for visible radiations which do not penetrate deeply, the surface might become hotter (hence re-radiation to the thermopile) than it would for the same amount of energy of wave-lengths at 4.4 μ, which penetrates more deeply into the layer of soot, hence is absorbed nearer the brass surface where conditions are more favorable for heat conductivity. It so happened that for the spectral regions of 0.95 μ, 4.4 μ, and 8.8 μ the incident radiation was of practically the same intensity.

In all cases the blackest obtainable deposits of any given source were investigated. The paraffin candle was discarded because of the difference in the boiling points of its constituents. The deposits were usually whitish. The rosin was burned in a sperm candle; and it, as well as camphor (which burns without the presence of other ingredients), tends to give granular brownish deposits having a reflecting power of about 1.3 per cent. in the visible spectrum. The "cold" deposits from a standard candle are fairly uniform, reflecting about 1.25 per cent. The "hot" deposits are much blacker and reflect about 1 per cent. Viewed at grazing emergence, the surfaces appear as smooth as polished mirrors.

The blackest obtainable "hot" deposits are made in the acetylene flame, the lowest observed reflecting power being 0.42 per cent., and the average deposit reflecting about 0.6 per cent., at 0.6 μ. The "cold" deposits, obtained by holding a piece of sheet iron against the flame and allowing the resultant smoke to deposit upon the brass block, give somewhat higher reflecting powers, which are of the order of 0.8 per cent. None of these deposits have the brownish appearance to be observed in all deposits of soot from burning camphor. All these deposits were obtained by using standard burners. To test the effect of combustion without air being mixed with the gas before ignition, a glass tube was drawn down to a point which then formed the "burner." The flame emits, of course, a dense cloud of smoke. The deposit upon the brass block was smooth and brownish in color, similar to camphor soot. The reflecting power (see

Table I, Acetylene, "no air") was 1.33 per cent., which is the average value of camphor soot.

In a previous paper,[15] which gives data on the absorptivity of an acetylene flame, attention was called to the peculiar selective absorption band in the visible spectrum, which was similar to bands found in metals, *e.g.*, nickel and platinum, which are in a colloidal state. Moreover, in the beginning of this paper attention was called to the seemingly colloidal properties of platinum black. Platinum black and acetylene soot are the blackest substances yet recorded; and of these the acetylene soot has the greater absorption. It is not unreasonable to consider the carbon particles (and the platinum in the electrolyte) to be in the colloidal condition, at the instant of disruption of the gas molecule. In the hottest part of the flame one obtains the finest particles, *i.e.*, the blackest surfaces. These surfaces, viewed at grazing emergence, appear as perfect mirrors, having a high reflecting power.

Acetylene soot has a very low heat conductivity which permitted warming of the superficial layers of a thick deposit of soot. The temperature rise was sufficient to cause re-radiation upon the thermopile, and, as explained elsewhere in this paper, the apparent reflecting powers at 4.4 to 2.4 μ were of the order of 2.6 to 3 per cent., when an equally black thin film reflected less than 1 per cent. By placing a thin sheet of glass in front of the thick film (this was possible for the region of 0.95 μ without disturbing the adjustments) which absorbed all the radiations of long wave-lengths, the reflecting power was reduced from 2.6 per cent. to 1.08 per cent., showing that the high value was erroneous. In practice a radiation instrument should, therefore, be covered with a film of acetylene which is less than 0.15 mm. thick.

The blackest deposits of soot are obtained by holding the metal plate in the flame. But this will be rarely possible with radiation instruments. Furthermore, unless one constructs a special burner, it is not possible to blacken large surfaces in the flame without having them streaked with grayish-colored material. One must, therefore, use cold deposits and standard material. The standard sperm candle is the most promising source, the reflecting power of the blackest surfaces being about

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[15] *Bulletin Bureau of Standards*, 7, p. 243, 1911.

1 per cent., in the visible spectrum, which is the order of accuracy of radiation work at the present day. It is difficult to remove fine dust from these surfaces, hence it appears advisable to use a hemispherical mirror to intercept the diffusely-reflected rays.

For the absorbing surface of a secondary radiometer which has been calibrated against a primary standard it seems desirable to use the best quality of lampblack paint, the vehicle being a volatile turpentine. If the turpentine has polymerized and dries slowly, then a mixture of turpentine and alcohol should be employed. The turpentine is, of course, used simply to render the lampblack adhesive, and it is used instead of a dilute alcoholic solution of shellac because, as already mentioned, the latter tends to produce a grayish surface. All these surfaces are, of course, perfectly matte. The lampblack paint is easily freed from dust, hence is to be preferred to soot when the instrument must be operated in the open air.

V. REFLECTING POWER OF PLATINUM BLACK.

The electrolytic deposits of platinum black were deposited upon sheet platinum 0.02 mm. in thickness and 0.5 by 4 to 5 cm. in area. These platinum sheets were then mounted upon the brass blocks, already described, by means of Khotinsky cement. The first surfaces were made from a solution of platinum chloride, which usually gave grayish deposits. After many attempts, which included Nos. 4 and 5, Table II, a new solution of chloroplatinic acid was prepared by dissolving a known weight of platinum (4 Gr. of sheet platinum) in aqua regia. This material was evaporated to as near dryness as possible over a water-bath. This evaporation process was repeated after adding hydrochloric acid. The resulting material, which is a thick, reddish syrup, contained 8.3 Gr. (theoretical value) of H_2PtCl_6. From this a solution of the proper concentration recommended by Kurlbaum[16] was made up, viz., 5 Gr. of H_2PtCl_6, 150 Gr. of water, and 0.04 Gr. of lead acetate. The deposits of platinum black were made by passing a current of 0.03 ampère per cm.^{2} of exposed surface, the time being varied from 1 to 7 minutes. By occasionally jarring the electrodes the escape of gas bubbles was prevented. This procedure seemed to assist in forming black deposits. The cathode (strip to be blackened) was, of course, placed between two strips of platinum, which formed the anode. The distance between the anode and cathode was about 2 cm. The platinum strips were made sufficiently long and every other precaution was taken so as not to contaminate the solution by acting upon the copper leads.

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[16] Kurlbaum, *Ann. der Phys.* (3), 67, p. 846, 1899.

The manner in which the reflecting power decreases with increase in thickness of the deposit is well illustrated in the samples, Nos. 14 to 20, given in Table II. The reflecting power is a function of the wave-length, a much thinner deposit being required to produce a maximum absorption for the spectral region of 4.4 μ than for the region of 8.8 μ. At normal incidence the thin deposits appear darker and more velvety than the thick ones, but a slight deviation from the normal increases the reflecting power, as illustrated in No. 4 at 8.8 μ. Moreover, some of the very dark, velvety, thick deposits tend to give high values beyond 4.4 μ, although they show an abnormally low reflection in the visible spectrum. This was definitely determined by repeated tests on No. 16, which was similar in appearance to No. 17. To the eye No. 16 appeared slightly darker than No. 12. The deposits Nos. 18 and 19 were on the opposite sides of a strip of platinum, deposited at the same time. The reflecting powers (1.78 and 2.13 per cent. respectively) are considerably different at 8.8 μ. Of course, this is quite a severe test of reproducibility. Deposits that were continued for more than 7 minutes became rough and nodular. From Table II it may be noticed that the deposition of platinum black should be continued for at least 5 minutes to obtain a maximum absorption at 4.4 μ; and the best practice is to continue the process 6 to 7 minutes, when the maximum absorption is attained at 8.8 to 2.4 μ. The reflecting power then rises gradually from about 1 per cent. in the visible to 3 per cent. at 24 μ.

The deposits are quite adhesive, so that if kept free from dust the reflecting power changes but little with age. This is illustrated in the two series of measurements on Nos. 18 and 20 at 4.4 μ, which were re-examined after an interval of about a month, when the apparatus was entirely readjusted and different-sized slit images were used. The ever-present particles of lint were first removed by blowing gently with the breath. In the second set of measurements on Nos. 18, 19, and 20 the observations at 0.95 μ and 4.4 μ were made in succession before removing the specimen. It is, of course, to be understood that, owing to the labor involved in making the adjustments of the quartz and fluorite plates, the regions of 8.8 μ and 24 μ were examined separately. Hence, the specimens were all examined in succession at 8.8 μ before turning to the region of 24 μ.

The deposit No. 19 was smoked with soot from a sperm candle which raised the reflecting power in the visible spectrum without materially affecting the region of 4.4 μ.

Chemically-precipitated platinum black was also examined. It is quite brownish in appearance. One of the three samples was a layer of the material pressed upon the brass block, as already described. The others were painted on the brass plates by means of a solution of alcohol and turpentine, which dries quicker than turpentine. In both cases the reflecting power is high (2 per cent.) in the visible, increasing to 12 per cent. at 24 μ. This is owing to the property of the material and not to the thickness of the layer. The thickness of the layer in the various samples examined varied from 0.1 to 0.3 mm. By mixing lampblack and platinum black, equal parts (by bulk), and applying it as paint, the reflecting power is raised in the visible and reduced at 24 μ. This specimen was then covered with soot and the reflecting power was reduced to about 1.4 per cent. Although the reflecting power is now more uniform throughout the spectrum, it is not more so than the electrolytic deposit, which reflects only about one-third as much energy. Hence, the precipitated material, or mixtures of the same, is less desirable than the best obtainable lampblack paints (see Table I).

In lampblack, difficulty was experienced in making measurements, owing to re-radiation which resulted from the low heat conductivity and consequent heating of the thick layers of soot. This was not experienced in platinum black, owing to better thermal conductivity. The glass window over the thermopile absorbed this re-radiated energy from the black surfaces. In the case of platinum black (which was more thoroughly studied than soot because it gives more permanent surfaces), the reflecting power at 0.95 μ was determined with a glass and with a rock-salt window on the thermopile. The values are in perfect agreement, showing that there was no re-radiation upon the thermopile when the rock-salt window was used. The values are, therefore, to be considered reliable, and the slight variations in the reflecting power observed in the table are owing to differences in the structure of the deposits. Even with the new solution one of the deposits came out quite grayish in appearance. This seemed to have been caused by excessive agitation of the electrolyte to keep the electrodes free from the stream of gas bubbles.

An examination of six commercial surface bolometers (twelve branches, or 24 surfaces) showed that all the herein-described deposits of platinum in which the deposition of platinum black was continued for at least 4 minutes were better than the surface of the best bolometer on hand. The bolometer surfaces (even the thick deposits) showed bright spots where the metal was exposed. One bolometer had a thin deposit, similar to the 1 to 2 minute deposits shown in Nos. 13 and 14, Table II. From this the conclusion is to be drawn that the correction for diffuse reflection from a commercial surface bolometer is from 2.5 to 3 per cent., or perhaps as high as 5 per cent. In fact, with the improved facilities now at hand it is better to obtain new data on the total radiation of black bodies, rather than attempt to correct the old data, which are now of historical interest.

With this end in view, now that the present research is completed, it is purposed to use the knowledge gained, as well as the hemispherical mirror and thermopile, in obtaining data on the constants which enter the Stefan law of total radiation.

VI. THE REFLECTING POWER OF GREEN LEAVES.

The first examination of diffuse reflecting power of growing leaves was undertaken in May, 1908, the apparatus employed being a bolometer, a mirror spectrometer, and a fluorite prism. The leaves were mounted upon a holder beside a silver comparison mirror, and the observations were carried out in the same manner as was employed in the determination of the reflecting power of plane mirrors.[17] The angle of incidence was 45°, and the distance of the reflecting surface to the spectrometer slit was about 6 cm. The source of light was a Nernst glower. The values thus obtained are, of course, only relative for the different wave-lengths. The observations extended to 3 μ (see Fig. 3), and in all cases there appeared to be a decrease in the amount of energy reflected with increase in wave-length. This seems plausible, for the increase in opacity with wave-length beyond 1.4 μ, which obtains in water, would decrease the amount of radiation that can return by internal reflection. The curve "Red Oak, II *a*," was obtained after the sample "Red Oak, II," had remained upon the spectrometer over night, when considerable of the moisture had evaporated. It is, therefore, to be expected that the reflecting power would be less than when the cells contained moisture.

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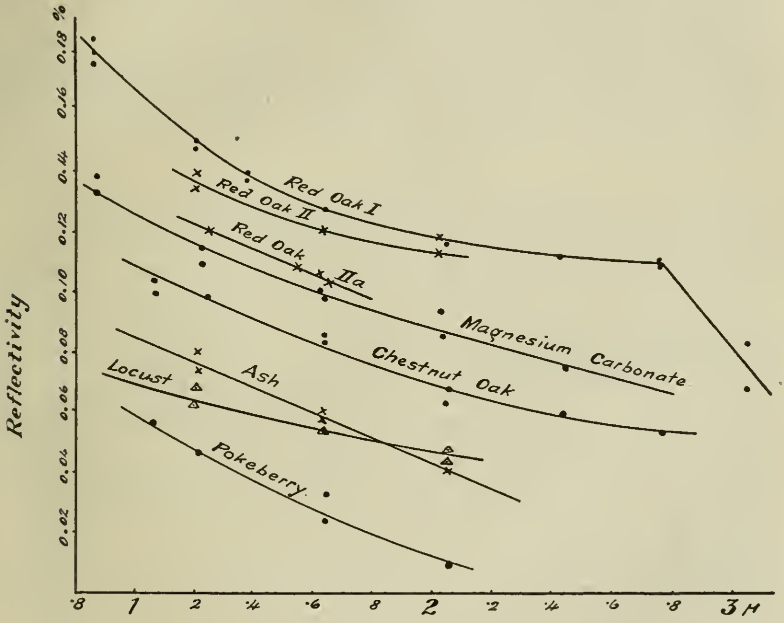
[17] *Bulletins Bureau of Standards,* 2, p. 457, 1906; 7, p. 197, 1911.

FIG. 3.



Reflecting Power of Green Leaves.

In the case of magnesium carbonate, the decrease in reflecting power with increase in wave-length might result from a decrease in refractive index, which obtains in all similar "transparent media." This decrease in reflecting power is more noticeable in the region of 4.4 μ.

In this year's work, unless otherwise noted, the green leaves were examined in the latter part of May. The oldest (darkest green) leaves were selected, which were entirely free from injury. The reflecting power is somewhat less for the fully-matured leaves of the oak and the tulip tree (Table III), gathered in July. The clover, locust, laurel, and lilac leaves appeared well matured when examined.

From Table III it appears that vegetation reflects about 25 per cent. of the solar rays. The value may be a little higher than this, for the absorption cell used with the acetylene flame produces an energy distribution which is somewhat richer in red and infra-red rays than obtains in average sunlight. This value cannot greatly differ from the true one, however; for, using monochromatic radiation corresponding closely with the color of leaves (green glass; $\gamma = 0.54\ \mu$), the observed reflecting power of clover, lilac, and tulip leaves is not much higher than for the composite rays, which have a maximum at 0.60 μ. These tests were, of course, applied on the same leaf by simply placing a green glass before the absorption cell. The mullein leaf gave

TABLE III.

Reflecting Power of Green Leaves.

Wave-length. λ max.	.54μ	.60μ
	%	%
Clover (*Trifolium pratense*)	23.9	21.3
Lilac (*Syringa vulgaris*), May 3	26.0	25.3
June 8		23.6
	(Transmission = 19.6)	
Locust (*Robina pseudacacia*), May 3		25.4
June 8		23.9
	(Transmission = 20.7)	
Tulip tree (*Liriodendron tulipifera*), May 3	28.1	27.2
July 29		22.0
Laurel (*Kalmia latifolia*)		23.2
Rear side		27.7
Basswood (*Tilia Americana*)		26.9
Elm (*Ulnus Americana*)		25.7
Oak (*Quercus rubra*)—Young leaf		29.3
Dark green		21.8
Mullein (*Verbascum thapsus*)		24.2

surprising results; the reflecting power differing but little from that of other leaves. Because of the densely woolly surface, the expectation was to observe a high reflecting power. Evidently the tomentous covering contributes but little in raising the reflecting power. This is of interest in connection with desert plants having a woolly covering. The transmission was difficult to observe, owing to the warming of, and the consequent re-radiation from, the leaves upon the thermopile. The leaf to be examined was placed over the thermopile, the distance between the two being about 1 mm. to avoid heat conductivity to the thermopile. The transmission of a leaf (after correction for reflection) is about 20 per cent. (Table III). The two kinds of leaves, lilac and locust, differed considerably in thickness.

According to the measurements of Brown and Escombe.[18] the absorption of leaves is 68 to 69 per cent. of the total solar energy. Their values for the loss of solar radiation by transmission through the leaf are of the order of 30 per cent., depending, of course, upon the kind of leaf. These values are in fair agreement with present observations, considering the nature of the material and the apparatus used. Brown and Escombe (*l.c.*) have also published values for the total energy expended in internal work, viz., the energy used for photosynthesis (about 1.5 per cent.) and the energy used in transpiration of water (10 to 60 per cent., depending upon the kind of leaf). They found that the maximum temperature excess above its surroundings, to which a leaf can be raised in still air, is about 0.02°.

All these data are very instructive when compared with the reflecting power of building material, *e.g.,* brick, marble, granolith, and asphalt, given in Table V. In the latter the energy absorbed is not utilized in internal work, and the temperature rises a very considerable amount, depending upon exposure to wind, etc. Hence, in marked contrast with vegetation, when the sun is obscured or has set, the building material continues for some time to re-radiate the energy absorbed during the daytime.

It is beyond the scope of this paper to discuss the economic importance which would result from the application of these data. Suffice it to say that until traffic demands the full width, a considerable portion of the total width of a street and sidewalk should be occupied by trees and grass, instead of asphaltum and granolith. The reflecting power of a green leaf, in different spectral regions, is given in Table V.

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[18] Brown and Escombe, *Proc. Roy. Soc., Lond.,* B, 76, p. 29, 1905.

VII. REFLECTING POWER OF PIGMENTS.

The powdered material was mounted upon the brass block (Fig. 1 D). In some cases the material was moistened with water containing a trace of gum arabic; but there was difficulty in causing the material to adhere to the block. This difficulty was overcome by putting a thin coat of shellac varnish upon the brass block. After the shellac had become quite dry a thick (0.3 mm.) layer of the powder was pressed upon the block and flattened with a plate of glass. The effect of smoothness usually was not noticeable. However, in substances having high metallic reflection, *e.g.*, silicates, carbonates, and sulphates, at 8 to 9 μ (see Table IV, quartz at 8.8 μ), the smoothness of the surface was of importance. For example, a rather coarse-grained sample of powdered feldspar reflected 10.3 per cent. at 8.8 μ. On pressing the material into a more compact mass, the reflecting power arose to 14.6 per cent.

Zirconium oxide mounted by the two methods gave concordant results. Owing to the high reflecting power of the material, so much energy was thrown upon the thermopile that the glass window, which absorbs about 15 per cent. of the radiations at 4.4 μ, became sufficiently warm to cause the galvanometer to drift. It was, therefore, impossible to obtain trustworthy values of the reflecting power of the white powders with the glass window in place. It was, therefore, replaced by a window of rock salt. When examining the black substances at 4.4 μ the opposite condition obtained. In comparison to the total amount reflected, the temperature rise was such that re-radiation from the lampblack became appreciable. The glass window had, therefore, to be used over the thermopile to absorb the radiations from the black substances.

As mentioned elsewhere, there is a distinction between the high reflecting power observed at 4.4 μ and at 8.8 μ. The high values (40 to 50 per cent.) at 4.4 μ are to be ascribed to internal reflection. On the other hand, it is a common property of insulators to be very opaque beyond 5 μ, and to have bands of selective reflection beyond 6 μ. For example, carbonates have bands of selective reflection in the region of 6.9 μ; sulphates and silicates have bands of strong selective reflection in the region of 9 μ. Hence, the high reflecting powers observed in the case of carbonates and silicates (Table IV) at 8.8 μ are due to selective reflection from the surface of the particles.

TABLE IV.

REFLECTING POWER OF PIGMENTS.

Wave-length. λ max.	.54μ	.60μ	.95μ	.95μ (red glass)	4.4μ	8.8μ	24.μ
	%	%	%	%	%	%	%
Cobalt oxide (Co_2O_3)		3.02	3.92 4.04 2.49		13.9	14.6 11.8	5.9
Copper oxide (Cu O)			23.5		15.2		4.4
Chromium oxide (Cr_2O_3)	24.1	27.0	44.6		32.9	5.0	8.2
Lead oxide (PbO)		51.8			50.6	25.6	9.5
Red iron oxide (Fe_2O_3)		26.3	41.0	53.6	29.9	3.7	9.1
Yttrium oxide (Y_2O_3)		73.8			34.4	11.1	10.
Lead chromate ($PbCrO_4$)	61.2	70.2			41.2	4.74	7.4
Aluminum oxide (Al_2O_3)		84.1	87.7		20.8	2.34 1.64	6.5
Thorium oxide (ThO_2)		86.1			46.9	7.11	10.
Zinc oxide (ZnO)		82.2	86.4		8.5	3.2 2.1	5.1
Magnesium oxide (MgO)		86.3			16.0	2.5	9.1
Calcium oxide (CaO)		85.4			22.3	3.6	6.2
Zirconium oxide (ZrO_2)	82.2	85.8	84.1	83.0	23.2	5.1	5.4
Lead carbonate ($PbCO_3$)		88.7 89.9	90.8 92.8 94.5		29.2	8.3 13.2	6.9
Magnesium carbonate ($MgCO_3$)		85.2	89.4		10.8	4.1	8.8
White paper			75.2		18.2	5.0	
Feldspar (KAl Si_3O_8)			86.7		38.2	10.3 14.6	9.7
" (cleavage)		39.4					
Bluestone (sandstone) (SiO_2)			18.4		8.1	17.6	11.0
Quartz (powdered French flint) (SiO_2)			81.0		41.5	7.9 13.4	9.0

The low reflecting power of the aluminum oxide at 8.8 μ is of interest, because the observations were made in the region of anomalous dispersion where the reflecting power is abnormally low,[19] followed by bands of metallic reflection at 12 to 14 μ. Zinc oxide also has a low reflection at 8.8 μ. The reflecting power of a plane, highly-polished surface is low and uniform throughout this region.[20] By pressing the powdered material into a smooth, compact mass the reflecting power (3.2 per cent.) was not materially increased. This shows that it is not a surface phenomenon, as found in silicates and carbonates. For example, in lead carbonate which was pressed into a smooth, hard mass, comparable with that of the zinc oxide sample just mentioned, the diffuse reflecting power was raised from 8.3 to 13.2 per cent. These surfaces, including zirconium oxide, which has a low reflecting power, appeared dull at normal incidence; but when viewed at grazing incidence appeared like highly-polished mirrors. The difference between "surface color" and "body color" is well illustrated in lead carbonate and in zinc oxide.

Lead oxide appears to have an extremely high reflecting power in the region of 8.8 μ, and by using a plane, highly-polished surface the reflection spectrum of this substance should be examined for residual rays in the region of 8 to 10 μ.

Many of the substances examined show a high reflecting power for the spectral region of 24 μ, from which it is to be inferred that they possess strong selective reflection in this region of the spectrum. It is, of course, already known that carbonates and silicates have bands of selective reflection in this region of the spectrum.

Mention was made in the beginning of this paper that the most efficient paint to protect a building from solar rays is one having a high reflecting power in the visible spectrum and a low reflecting power in the region of 8 to 9 μ. Of the various materials used in paints, zinc oxide would be the most efficient radiator in the region of 8 to 10 μ, but it does not appear to reflect so highly as lead carbonate in the visible and the violet. Mixed with an oil, however, the lead paint does not appear so white; and it has a lower emissivity at 8.8 μ. Hence, from a radiometric standpoint, pure zinc oxide and lead carbonate appears to be the most promising paint. But the use of mixtures of calcium carbonate (carbonates), calcium or barium sulphates (sulphates), China clay, or silica (silicates), which are often mixed with these primaries,[21] *e.g.,* with zinc oxide, does not appear advisable, viewed from a radiometric standpoint, for they all indicate a low emissivity in the infra-red. In the complete research it is purposed to include measurements on various samples of white paints.

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[19] See "Investigations of Infra-red Spectra," Publication No. 97, p. 18, Carnegie Institution, 1908.

[20] Carnegie Publication, No. 97, p. 17.

TABLE V.

MISCELLANEOUS SUBSTANCES.

Wave-length. λ max.	.60μ	.95μ	4.4μ	8.8μ
	%	%	%	%
Brick:				
Light buff	48.4			
Darker	40.0			
Red brick	30.1			12.4
Darker and glazed	23.4			
White marble ($CaCO_3$); ground; unpolished	53.5		6.4	5.1
" " " " (cleavage)	40.8			
Indiana limestone ($CaCO_3$)	42.9		20.3	5.0
Granolith (pavement)	16.9			
Asphalt	14.8			
" (free from dust)	7.2			
Slate (dark clay)	6.7			20.0
Brown sand	25.7			
Black velvet	1.75		3.66	2.7
Black felt	13.9	21.2		
Deep blue (navy department)	17.0			
Lighter shade	18.2			
Blue flannel	17.5			
Leaf (tulip tree)	21.9	38.0	5.6	

VIII. REFLECTING POWER OF MISCELLANEOUS SUBSTANCES.

In Table V are given the data obtained on various substances not closely related to the groups of substances already described. The ground and the cleavage surface of white marble illustrate the effect of grain size upon the reflecting power, as mentioned in the beginning of the paper. The brown sand examined illustrates the average reflection from material obtainable along roadsides. Fine dust would probably have a higher reflection. The effect of fine dust upon asphaltum is also shown in this table. The sample examined was a piece of road material which was being removed after some years' usage. In the same manner the granolith was a piece of pavement. The latter sample, however, was washed and free from dust. Of the other building materials the slate used in roofing is of interest, for it reflects only about 6.7 per cent. of the solar rays.

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[21] *Proc. Amer. Soc. for Testing Materials,* 11, p. 226, 1911.

For convenience in tabulating, the data on "bluestone" (the dark-colored sandstone extensively used in buildings) are given in Table IV. This material cleaves into thin, flat laminæ. The reflecting power at 8.8 μ and 24 μ is very high, owing to the bands of selective reflection (silica) and the presence of fine crystal surfaces. The reflecting power of powdered feldspar and of quartz ("French flint") is also given in Table IV.

Black velvet has a very low reflecting power. The reflecting power of the sample of black felt recorded in Table V was examined several times on different days. The values were always high. In comparison, visually, with the black velvet the sample appeared much lighter in color.

Washington, D. C., Oct. 5, 1912.

Lignite in Tuscany. Anon. (*Mon. Sci. Mercure,* ii, 848, 61.)—The deposits of lignite in Tuscany are of great importance to the whole of Italy, for the beds at San Giovanni, 45 kilometres (28 miles) from Florence, furnish two-thirds of the total supply. The content of these beds is estimated at 8,000,000 tons. The product contains 40 to 45 per cent. of water and has a calorific power of 3,400 calories in the dry condition. It is marketed in the form of briquettes. In 1909 there were 176,490 tons sold.

Protecting Iron and Steel from Corrosion. Anon. (*Brass World,* viii, 8, 272.)—Gilbert Rigg, of the New Jersey Zinc Company, has discovered that sodium tungstate prevents the rusting of iron and steel. A solution of 1 part of sodium tungstate in 2,000 parts of water is efficient. This is applied to zinc oxide paints, and zinc tungstate is ground with the paint and protects iron and steel.

Colloid Phenomena in Concretions. E. Geinitz. (*Centr. Min.,* 1912, 282.)—The concentric structure of clay-stone concretions, and the striated cylindrical masses observed in flint and usually regarded as problematical organisms, are most readily explained as the result of diffusion in colloid substances, such as has been shown by Liesegang to be the origin of agate structures.

NOTES FROM THE U. S. BUREAU OF STANDARDS.

COMPARISON OF FIVE METHODS USED TO MEASURE HARDNESS.[1]

By Ralph P. Devries,
Assistant Physicist, Bureau of Standards.

In order to ascertain the concordance which might be expected in the five leading instruments for testing the hardness of metals, an investigation was made at the Bureau of Standards, the report of which is about to appear in the series of Technologic Papers of the Bureau. The static tests of hardness studied are the cone and Brinnell Sphere. The dynamic tests are the Shore Scleroscope, Brinnell Sphere, and Ballantine. The Bauer Drill test for measuring the work-ability of metals is also included. The tests were made on a series of metals which ranged from very hard steels to comparatively soft alloys. The laws governing the resistance to indentation are experimentally deduced for spheres of different sizes and cones of different degrees of angular open-

Hardness Numerals of Different Metals by Five Methods of Test.

Metal	Shore scleroscope	Hardness numeral				Bauer drill test	Ballantine test
		Brinnell		Cone, 90° cone	Test, 60° cone		
		$\frac{P}{2\pi t R^1}$	$\frac{P}{t}$				
Carbon steel	86.1	641	4550	....	....	....	3.2
Silicon steel	33.6	261	865	331	130	....	3.0
Manganese steel	29.5	179	641	368	124	....	3.3
Cast iron No. 1	33.3	149	538	191	68	....	3.2
Cast iron No. 2	32.9	172	590	231	79	2.29	3.3
Bessemer steel	26.6	188	428	260	76	....	3.3
Tool steel	37.8	289	1230	....	....	....	3.3
Cu.-sn. alloy 1	42.4	110	460	130	50	.73	3.1
Cu.-sn. alloy 2	25.5	105	323	149	54	1.04	3.2
Cu.-sn. alloy 3	22.1	94	289	122	48	1.24	3.4
Copper 4	15	89	235	114	38	1.88	3.2

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[1] Abstract of Technologic Paper of the Bureau of Standards, No. 11 (in press).

ing. The effect of elastic deformation of the sphere upon the results of sphere tests is determined by means of a method which involves the exact measurement of the depth of indentation. This method of measurement is also applied to the cone tests. The study of the individual methods shows (1) the possibility of obtaining rational hardness numerals for the cone and sphere tests, and (2) that the dynamic tests for hardness do not agree in general with the results of static tests.

SODIUM OXALATE AS A STANDARD IN VOLUMETRIC ANALYSIS.[1]

THIS circular gives a *résumé* of the work done on sodium oxalate at the Bureau of Standards and elsewhere which has led to its selection by this Bureau as a primary standard in volumetric analysis. This material is now issued in a form similar to other standard analyzed samples, of which about forty have already been prepared for distribution to the public. The circular describes the methods of preparation, and testing of the sodium oxalate. Its stability is discussed, as well as its uses in oxidimetry and acidimetry, although it is especially recommended as an oxidimetric standard.

INSTRUMENTS AND METHODS USED IN RADIOMETRY.[2]

By W. W. Coblentz,

Associate Physicist, Bureau of Standards.

IN this paper is given an account of the recent development and improvement of spectral radiation instruments. This includes air and vacuum bolometers, thermopiles, and radiomicrometers; new combinations of instruments; linear and surface thermopiles of bismuth-silver of high sensitivity; and (Note I) the Callendar radio-balance.

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[1] Abstract of Circular of the Bureau of Standards, No. 40 (in press). Copies may be obtained upon application.

[2] The full paper will be found in *Bulletin of the Bureau of Standards,* vol. ix. Separates may be obtained upon request addressed to the Bureau.

The aim of the research was the production of instruments of precision rather than the attainment of high sensitivity. The vacuum bolometer was found to excel all the other types of radiometers in accuracy in speed and in range of sensitivity. The instrument is difficult to handle, and for most work the bismuth-silver thermopile is recommended. The latter is as sensitive as a bolometer. The novelty of this type of thermopile is the solid surface which is exposed to radiation, thus utilizing all the energy from a spectral line with the type of iron-constantan thermopile in present use. The various modifications of these thermopiles are applicable to radiation pyrometers, sunshine recorders, and thermogalvanometers for measuring weak alternating currents.

THE PHYSICAL TESTING OF MECHANICAL RUBBER GOODS.[1]

THIS circular outlines the methods used at the Bureau of Standards for determining the physical properties of rubber, and gives a brief description of the processes of manufacture, beginning with the collection of crude rubber, and also processes for reclaiming rubber. The tension test is the most widely applicable, being used to determine the more important physical properties, such as elasticity, strength, and ultimate elongation. Machines and apparatus for conducting these tests have been designed and constructed at the Bureau of Standards. The apparatus for determining elasticity is adapted to test six samples at once, thus introducing considerable saving of time over the method usually followed. This test consists in stretching specimens to a definite elongation and measuring the permanent extension or set after a specified interval of rest. A similar piece of apparatus has been designed for determining the reduction in tension when rubber is stretched and held at a definite elongation. Motor-driven machines with a number of speeds are used for testing tensile strength and ultimate elongation, and on all testing machines a specially-designed grip is used for holding the specimen.

In preparing samples for test a die is used which insures uniformity of size. Gauge marks are placed on the test piece from which the permanent set and ultimate elongation are measured. Results of tests are shown graphically, illustrating the characteristics of various rubber compounds. The effect of continued heat at 160° F. on different rubbers is shown, and these tests are being extended with a view to establishing an accelerated aging test. An analysis of the distribution of stress in a ring test piece is given showing that as a result of the uneven distribution of stress the ring method does not develop the full tensile strength of rubber. This theory is verified by the results of tests which are given in tabular form.

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[1] Circular No. 38, Bureau of Standards.

DETERMINATION OF MANGANESE AS SULPHATE AND BY THE SODIUM BISMUTHATE METHOD.[1]

By William Blum.

Of the three forms most commonly used for the gravimetric estimation of manganese, that depending upon weighing as Mn_3O_4 is generally admitted to be inaccurate; while, as shown by Gooch and Austin, the composition of manganese pyrophosphate, obtained by ignition of the manganese ammonium phosphate, depends very directly upon the conditions of precipitation, and usually yields high results under the conditions recommended by them. Manganous sulphate is, therefore, the only compound adapted to accurate weighing of this element, either in gravimetric analysis or in obtaining a definite amount of manganese as a primary standard. Of the various volumetric methods considered, the bismuthate method appeared to be most nearly free from the influence of the precise conditions of operation, and therefore most suitable for use as a standard method.

This method depends upon the oxidation of manganese to permanganic acid by sodium bismuthate in nitric acid solution. After filtration through asbestos to remove the excess of bismuthate, ferrous sulphate is added in slight excess, which is then titrated with permanganate of known manganese value and of known ratio to the ferrous sulphate. The method of standardizing the permanganate is, of course, fundamental, and forms the principal subject of this paper. The manganese value may be determined by two general methods: (*a*) titration of a known amount of manganese, *e.g.*, as $MnSO_4$, under the conditions of operation; and (*b*) calculation from the oxidizing value of the permanganate, derived from some accurate oxidimetric standard, such as sodium oxalate. The former would be more satisfactory, provided a simple and accurate means of obtaining a known amount of manganese is available. Otherwise the latter is preferable, though it involves the use of a conversion factor, which may be either theoretical or empirical.

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[1] Abstract of Scientific Paper No. 186. The full paper will appear in the *Bulletin of the Bureau of Standards,* and separates may be obtained upon application.

The author employed sodium oxalate for this purpose and used the theoretical conversion factor, after having shown that if a given amount of permanganate be reduced and reoxidized by bismuthate it is equivalent in oxidizing power to the original permanganate. Since, however, Brinton and others claimed that the sodium oxalate values were one per cent. lower than those derived from manganous sulphate, the subject was studied in further detail. Special precautions were observed in the preparation and preservation of the materials and solutions, and the titrations were conducted entirely with weight burettes. A study of the standardization of permanganate with sodium oxalate showed that the conditions recommended by McBride must be slightly modified for use with 0.03 N permanganate, the strength usually employed for the bismuthate method; since the relative errors caused by variation in conditions with 0.03 N permanganate may be much larger than with 0.1 N. By the use of a small volume in the titration the errors from this source are reduced to a minimum.

Results obtained by evaporation of a manganous sulphate solution depend entirely upon the time and temperature of the final heating, which point was investigated. It was found that heating for a considerable period at temperatures of 450–500° is necessary to obtain anhydrous normal manganous sulphate, and that the salt begins to decompose at temperatures from 550°–600°, *i.e.*, incipient to dull red heat. Solutions of known manganese content were prepared by solution of a definite weight of manganous sulphate which had been heated to constant weight at 450°–500°.

A study of the effect of conditions upon the bismuthate oxidation showed that for amounts of manganese up to 0.05 gramme accurate results may be obtained over a wide range of conditions, viz., at from 5° to 25° in a volume of 50 to 150 c.c., containing 20 to 40 per cent. nitric acid by volume, filtration after standing one-half minute or one-half hour with bismuthate; addition of ferrous sulphate immediately or after one-half hour. The results were accurate in the presence of as much as three grammes of iron. Addition of phosphoric acid to the ferrous sulphate solution rendered the end points more distinct. The only conditions found which yielded inaccurate results were (*a*) deficiency of nitric acid, (*b*) failure to agitate after addition of bismuthate, and (*c*) allowing the solution to stand after addition of the excess of ferrous sulphate. For analyses of rich ores and similar high-grade materials, the use of 0.1 N permanganate is recommended, permitting the use of about 0.1 gramme sample.

Experiments upon seven permanganate solutions, of different strengths (0.03 N and 0.1 N), prepared from different sources, showed that the values derived from sodium oxalate and manganous sulphate agreed in every case to within one part in five hundred. The accuracy of these values was confirmed by analysis of specially purified potassium permanganate crystals and by additional experiments upon the reduction and reoxidation of permanganate solutions. Comparative analysis of the Bureau of Standards manganese ore, as well as other ores, showed that the tendency of many of the commercial methods is to yield high results for manganese.

The bismuthate method is recommended as equal or superior to any other known methods for the determination of manganese, whether present in large or small amounts.

Active Modification of Nitrogen Produced by the Electric Discharge. R. J. STRUTT. (*Roy. Soc. Proc., Ser. A.*, lxxxvi, 262.) —The conclusions reached are: (1) Active nitrogen emits its energy more quickly and reverts sooner to ordinary nitrogen if it is cooled. This is apparently a unique instance of a chemical change accelerated by cooling. (2) If the glowing gas is compressed to a small volume, it flashes out with great brilliance and exhausts itself. This proves that the glow-transformation is polymolecular; *i.e.*, that more than one molecule must take part in it. (3) Active nitrogen may revert to ordinary nitrogen in two distinct ways. One is a volume change accompanied by glow, the other a surface action of the walls of the vessel without glow. This is analogous to the behavior of oxyhydrogen gas in its transformation to water, which may be either a surface or volume effect.

THE FRANKLIN INSTITUTE

(*Proceedings of the Stated Meeting held Wednesday, October 16, 1912.*)

Hall of The Franklin Institute,
Philadelphia, October 16, 1912.

President Walton Clark *in the Chair.*

Additions to membership since last report, 25.

Mr. Robert S. Perry was elected to fill a vacancy existing on the Board of Managers.

Following the meeting of the Institute for the transaction of this business, a joint meeting was held with the Philadelphia Section of the American Institute of Electrical Engineers.

President Clark introduced Mr. H. Clyde Snook, President of the Roentgen Manufacturing Company, Philadelphia, and then called on Mr. H. A. Hornor, Chairman of the Philadelphia Section, to preside.

Mr. Snook presented the paper of the evening, entitled "Recent Developments in Radiography."

The speaker reviewed the improvements made during the past several years in X-ray apparatus, and described the various devices used by the radiographer. Considerable attention was given to the several portable X-ray outfits intended especially for use in the army and designed to be transported by horse-drawn or motor-propelled vehicles.

Numerous lantern slides of radiographs and apparatus were shown, and several demonstrations were made on a complete X-ray apparatus especially installed for the purpose. First announcement was made of a new form of X-ray tube with a radium regulator. In this device clevite, an ore of uranium, is decomposed by the action of the current and emanates gaseous helium, which in turn regulates the vacuum in the tube.

The paper was discussed by Mr. Stratton, Dr. Goldsmith, Mr. Hornor, and others.

At the close of the discussion President Clark extended the thanks of the Institute and Mr. Carl Hering the thanks of the Philadelphia Section of the American Institute Electrical Engineers to the speaker.

The meeting then adjourned.

R. B. Owens,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, October 2, 1912.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 2, 1912.

MR. WILFRED LEWIS *in the Chair.*

The following report was presented for reconsideration:

No. 2514—Kennicott Water Weigher. Scott Award confirmed.

The following report was presented for final action:

No. 2513—McKee's Printing Plate and Process. Scott Award. Adopted.

The following report was presented for first reading:

No. 2499—Santo Vacuum Cleaner.

The following application was accepted for examination:

No. 2520—De Vos's Rolling Sector Boat-Davit.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday, October 3, 1912, at 8 o'clock P.M., with Dr. George A. Hoadley in the chair.

The Chairman introduced Prof. Robert Kennedy Duncan, Director Industrial Research and Professor of Industrial Chemistry, University of Pittsburgh, Pittsburgh, Pa., and University of Kansas, Lawrence, Kan., who delivered a lecture on "Industrial Research."

Among other examples of the fruits of industrial research, Dr. Duncan mentioned those of the discoveries of methods of producing synthetic rubber and synthetic indigo. He spoke of the large field of discovery still open to the experimentalist with waste products, etc.

Following his lecture, Dr. Duncan outlined the scheme of research fellowships in operation at Pittsburgh and Kansas under a system inaugurated by himself some six years ago and now grown to large proportions.

The thanks of the meeting were extended Dr. Duncan.

Adjourned.

R. B. OWENS,
Secretary.

Mechanical and Engineering Section.—A meeting of the Section was held in the Hall of the Institute on Thursday, October 10, at 8 o'clock P.M., with Mr. George R. Henderson in the chair.

The Chairman introduced Professor Gaetano Lanza, of The Baldwin Locomotive Works, who read a paper on "The Testing of Full-Size Pieces under Practical Conditions, Together with Locomotive Testing in the United

States." The paper was illustrated by lantern slides and discussed by several members and visitors.

Mr. Waring, of the Pennsylvania Railroad Company, Altoona, Pa., was introduced by the Chairman and described some of the special slides shown.

The thanks of the meeting were extended to Professor Lanza.

Adjourned.

FRANK B. STEM,
Secretary.

MEMBERSHIP NOTES.

Elections to Membership.

RESIDENT.

MR. WM. FRY JAMES, 6920 Boyer Street, Mt. Airy, Philadelphia, Pa.
MR. FRANK STEM, 608 Chestnut Street, Philadelphia, Pa.

NON-RESIDENT.

MR. F. S. STEVENS, Philadelphia & Reading Railway Company, Reading, Pa.
MR. C. D. YOUNG, Pennsylvania Railroad Company, Altoona, Pa.
MR. J. H. FULMOR, Pennsylvania Railroad Company, Pottsville, Pa.
MR. C. M. HARRIS, The Washington Terminal Company, Washington, D. C.
MR. J. TURNER MOORE, President Reading-Bayonne Steel Casting Company, Reading, Pa.
MR. NATHAN C. JOHNSON, 109 Luzerne Avenue, Pittston, Pa.
PROF. L. A. HERDT, McGill University, Montreal, Canada.
MR. G. W. CHANCE, Bristol, Pa.

ASSOCIATE.

MR. FRANKLIN P. MCCONNELL, 100 South Fourth Street, Darby, Pa.

Changes of Address.

MR. MORRIS KNOWLES, 2548 Oliver Building, Pittsburgh, Pa.
MR. HORACE C. KNERR, Wirt Electric Specialty Company, Primos, Pa.
PROF. J. AMBROSE MOYER, State College, Pa.
MR. E. E. KELLER, care of Detroit Insulated Wire Company, Wisson Avenue, Detroit, Mich.
MR. COLEMAN L. NICHOLSON, 117 Argyle Road, Ardmore, Pa.
MR. C. R. COLLINS, Hoge Building, Seattle, Wash.
PROF. L. F. RONDINELLA, High School for Boys, Forty-eighth and Walnut Streets, West Philadelphia, Pa.
PROF. L. M. HAUPT, Cynwyd, Pa.
MR. GEORGE MACLEAN, 18 West Thirty-fourth Street, Astor Court Building, New York City, N. Y.
MR. ARTHUR R. EDGERTON, Gardiner, Douglas County, Oregon.
J. M. GAZZAM, ESQ., 265 South Nineteenth Street, Philadelphia, Pa.
MR. KERN DODGE, Morris Building, Philadelphia, Pa.

Mr. Harold M. Bush, 136 East Gay Street, Columbus, Ohio.
Mr. T. Broom Belfield, 1905 Spring Garden Street, Philadelphia, Pa.
Rear Admiral Jos. B. Murdock, U.S.N., General Board Navy Department, Washington, D. C.
Mr. Charles E. Hubsch, 2019 South Eighteenth Street, Philadelphia, Pa.
Mr. Louis B. Whitney, Room 2444, Henry W. Oliver Building, Pittsburgh, Pa.
Mr. Charles H. Fish, P. O. Box 1593, Boston, Mass.
Mr. Mark W. Marsden, Logan Station, Philadelphia, Pa.
Mr. Benj. W. Carskaddon, 42 North Owen Avenue, Lansdowne, Pa.
Mr. Jos. S. Hepburn, Columbia University, Department of Biological Chemistry, 437 West Fifty-ninth Street, New York City.
Mr. Lightner Henderson, 1515 Monroe Building, Chicago, Ill.
Mr. G. H. Calkins, 10th Floor Electric Building, Buffalo, N. Y.
Rear Admiral John R. Edwards, U.S.N., President Board of Inspection, for Shore Station, Navy Department, Washington, D. C.
Mr. William G. Rogers, 2131 Pacific Street, Philadelphia, Pa.
Mr. C. W. Allen, 523 Oley Street, Reading, Pa.

NECROLOGY.

John Thomas Killé, a veteran of the iron industry and life member of the Institute, passed away on June 18, 1912, over 92 years of age. He was a native of Philadelphia, born in the southern section of the city, May 31, 1820. He was given a careful education in private schools, where he evinced a special aptitude for linguistics, acquiring, in his school years, a fluent mastery of French, and subsequently an almost equal proficiency in German and Italian. His active life began at an early age with the management, after his father's death, of the family interests in a wholesale dry goods house and in some cotton mills in Manayunk, in which connection he gave proof of business ability of a high order. These abilities opened the way to his being chosen, early in 1855, as secretary and treasurer of the Cambria Iron Works, under the presidency of Charles W. Wood. He continued in both capacities through a quarter of a century and as treasurer of the corporation through another ten years, retiring in 1890, after nearly a half-century of active business life. The qualities of direction and conservation, of forcefulness and foresight, demanded in the upbuilding of a great industrial organization like the Cambria Iron Works, were contributed in ample measure by its secretary-treasurer. Of the belching smokestacks that withstood the raging flood at Johnstown, and that are still telling of the industrial life below, some of the most prominent may be regarded as monuments to the sagacity, the industry, and the honesty of John Thomas Killé.

In The Franklin Institute this thoughtful worker also has a monument in the work of advancement which his generous bequest is helping to enlarge.

L. E. L.

Mr. James Rawle was born at Lancaster, Pa., in 1842. He was graduated a Bachelor of Arts from the University of Pennsylvania in 1861, and received his Master's Degree in 1864. He adopted the profession of civil engineer, and from 1862 to 1865 was a member of the corps on the construction of the Philadelphia and Erie Railroad.

He became connected with the J. G. Brill Company, of Philadelphia, in 1872, and was for many years its secretary and treasurer. On the death of George M. Brill, in 1906, he was elected president of the establishment. His death occurred on May 1, 1912, at Bryn Mawr, Pennsylvania.

Mr. Rawle was a director of many Philadelphia banks, and was for several years an officer of the First Troop, Philadelphia City Cavalry. He was elected to membership of The Franklin Institute in 1903.

Mr. John Alwine, Jr., Baltimore, Md.
Mr. Wm. R. Beal, Newburgh, N. Y.
Major Wm. H. Lambert, Mutual Life Building, Philadelphia, Pa.

LIBRARY NOTES.

Purchases.

ADAMS, H.—Theory and Practice in Designing. 1911.
SMITH, G. F. H.—Gem-stones. 1912.
RECORD, S. J.—Identification of the Economic Woods of the United States. 1912.
DANA, R. T., and W. L. SAUNDERS.—Rock Drilling. 1911.
HUDSON, C. W.—Notes on Plate Girder Design. 1911.
POTTS, H. E.—The Chemistry of the Rubber Industry. 1912.
BRISLEE, F. J.—An Introduction to the Study of Fuel. 1912.
FREITAG, J. K.—Fire Prevention and Fire Protection. 1912.
FOURNIER D'ALBE, E. E.—Contemporary Chemistry. 1911.
SCHNEIDER, N. H.—Dry Batteries. 1910.
SCHNEIDER, N. H.—Modern Primary Batteries. 1910.
INGALLS, J. M.—Interior Ballistics. 1912.
LUCKE, C. E.—Power. 1911.
CHALKLEY, A. P.—Diesel Engines for Land and Marine Work. 1912.
CHAPIN, H. M.—How to Enamel. 1911.
KERSHAW, J. W.—Elementary Internal Combustion Engines. 1912.
BOOTH, W. H.—Liquid Fuel and its Apparatus. 1912.
CARSLAW, H. S.—Introduction to the Theory of Fourier's Series and Integrals. 1906.
ROSCOE, H. E., and C. SCHORLEMMER.—A Treatise on Chemistry, vols. 1 and 2, ed. 4. 1907 and 1911.
NORTH, S. H.—Oil Fuel. 1910.
BOECKMANN, F.—Celluloid. 1907.
CROSS and BEVAN.—Researches on Cellulose. (1905-1910.) 1912.
SEYMOUR, A.—Modern Printing Inks. 1910.

IDDINGS, J. P.—Rock Minerals. 1911.

LOVE, A. E. H.—Some Problems of Geodynamics. 1911.

SCHNEIDER, N. H.—How to Install Electric Bells, Annunciators and Alarms. 1910.

SCHNEIDER, N. H.—Study of Electricity for Beginners. 1910.

SCHNEIDER, N. H.—Electrical Circuits and Diagrams, pt. 2. 1911.

Gifts.

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Ohio State University, Catalogues 1910–1911, 1911–1912. Columbus, 1911–1912. (From the Registrar.)

Utah Agricultural College, Catalogue 1912–1913. Logan, 1912. (From the College.)

Wisconsin Agricultural Experiment Station, Annual Report, 1911. Madison, 1911. (From the Station.)

American Philosophical Society, Transactions, vol. 22, part 2. Philadelphia, 1912. (From the Society.)

British Columbia Minister of Mines, Annual Report, 1911. Victoria, 1912. (From the Minister.)

Oklahoma State University, Catalogue 1903–1904, 1909–1910, 1911–1912. Norman, 1903–1912. (From the Registrar.)

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CURRENT TOPICS

Preservation of Mine Timbers. ANON. (*J. Mines Met.*, I, 5.)—The value of timber for mines depends on its strength, and this article gives the crushing strength of many kinds of timber. It is shown that very dry wood has a crushing strength 40 per cent. higher than wood in the ordinary condition of dryness. As most mines are damp, attempts are made to keep the timbers dry by impregnating them with metallic salts or tar derivatives, but without marked success. The salts wash out and the tar compounds keep the wood constantly damp. The merits of "Aczol," a metallic phenate, are discussed, and it is claimed that it increases the resistance of the wood, prevents the absorption of moisture, and acts as a germicide.

New Process of Seasoning Wood. ANON. (*Engineer,* cxiii, 463.)—A tank filled with a solution containing 5 per cent. resin, 10 per cent. borax, and a little sodium carbonate has on its bottom a lead plate connected to the positive pole of a dynamo. Timber is stacked on the plate till the tank is full; another lead plate is superimposed and connected to the dynamo. On passing a current sap is driven out, and the resin and borax take its place. The results are claimed to be highly satisfactory even with green timber.

Geological Formation of Tin Deposits. H. G. FERGUSON and A. M. BATEMAN. (*Econ. Geol.,* vii, 209.)—The distribution of the tin deposits throughout the world, and the geology, are discussed. Tin deposits are associated with acid intrusives and may vary in age from Archean to late Tertiary. The most important of its mineral associates are quartz, feldspar, mica, tourmaline, pyrite, arsenopyrite, and topaz, fluorite, etc. The formation of the cleavages may be considered one of the last phases of the work of the acid extract in the magma. It involves the addition of silica, boric acid, fluorine, and tin oxide, and often of lithium oxide, potassium oxide, and alumina, and the abstraction of the oxides of calcium, magnesium, and sodium, and sometimes of potassium and aluminum. The formation of the cassiterite itself, which occurs by the reaction, $SnF_4 + 2H_2O = SnO_2 + 4HF$, may have taken place under various conditions. Cassiterite may be found, (1) as an original constituent of granite and pegmatite, (2) as a result of pneumatolysis and pneumatolytic metasomatism, (3) as a true contact metamorphic mineral, (4) deposited under hydrothermal conditions or (5) at atmospheric pressure in the deposits of thermal springs.

Steel. J. W. RICHARDS. (*Met. Chem. Eng.*, x, 265.)—The proposal is made that "steel" be the generic name for all varieties of usefully malleable iron with less than 2.2 per cent. of carbon. This term would then include wrought iron, puddled steel, blister steel, cemented bar, single—and double—shear steel, ingot iron, soft steel, mild steel, C steel, and alloy steels. The iron of commerce would then be divided; that which is usefully malleable being known as "steel," and what is not usefully malleable known as "cast iron."

Production of Hydrogen. LEPSIUS. (*J. Gas Lighting*, cxvii, 896.)—The method pursued on a manufacturing scale at the Chem. Fabrik Griesheim-electron is the electrolysis of a solution of sodium chloride. A diaphragm of cement, not attacked by chlorine and alkali, is used, and the electrodes are iron and carbon plates. The hydrogen is obtained as a by-product in the manufacture of chlorine, according to the reaction:

$$2NaCl + H_2O = Na_2O + 2Cl + H_2.$$

One ton of salt yields 7,000 cubic feet of hydrogen. The Griesheim works, using 15,000 horse-power, produce 6 tons, or 245 million cubic feet of hydrogen per annum.

Yellow Flame Arcs. M. SOLOMAN. (*Electr.*, lxix, 130.)—The success of the flame arc is due more to Bremer and to other carbon producers than to the arc lamp manufacturers. The cores are made by mixing finely-ground carbon and fluoride with a potassium silicate solution, pressing it into a core canal, and drying. In standard carbons the core mixture is 50 per cent. fluoride, giving the total fluoride equal to about 12–15 per cent. Calcium fluoride, cerium fluoride, and strontium fluoride are used to produce yellow, white, and red arcs respectively. The conductivity of the carbon is increased by a metal core. Different types of lamps and carbons are compared as to cost per hour and efficiency, showing the behavior of the lamps at various values of voltage and ampèrage. An ordinary negative carbon gives the best results. When carefully compared on the cost per candle-hour basis, the cost of metal cored and plain carbons is about equal.

Brownian Movements. S. LIFCHITZ. (*Comptes Rendus*, cliv, 1084.)—It has been previously shown that the phenomenon of Bjerknes was insufficient to explain the displacement of particles of smoke by a condenser spark discharge. In this paper the eddies caused by the spark are investigated. Photographs are shown of the case when the "acoustic" oscillations were equal to 6.8 millions per second. Certain points on the axes of the whirlpools are apparently stationary and others move appreciably. At lower frequencies the trajectories have greater curvature, and the explosions produce a general displacement of all the particles.

Distribution of the Active Deposit of Radium in an Electric Field. E. M. WELLISCH and H. L. BRONSON. (*Phil. Mag.*, xxiii, 714.)—These experiments to explain the mechanism involved in the transmission of the active deposit of radium to the electrodes in an electric field, or to the exposed solid surfaces in the absence of such a field, show a decided interaction between the " restatoms " and the ions produced by the radiations which accompany the formation of these particles. There appear to be no negatively-charged carriers, all the so-called anode activity being due to the diffusion of uncharged carriers. The effect on the distribution of the passage of Röntgen rays through the gas is appreciable only when the activity and ionization are far from saturation. Lack of agreement in the results of previous investigations is traced to the fact that the potentials employed were often far from sufficient to satisfy the radioactive ions. The difficulty of obtaining saturation both for cathode activity and for α-ray ionization is explained by the hypothesis that the α-particles produce " neutrons," *i.e.*, molecules in an electrically neutral but unstable condition. some of which are subsequently resolved into ions, probably by collision with ions already produced in the ionization columns.

The " Luminator " Treatment of Water. H. B. LAKE. (*J. Soc. Chem. Ind.*, xxxi, 57.)—Very hard water was passed through tubes and V-shaped troughs of aluminum at different rates and under different conditions of light. Determinations of total and permanent hardness, " soluble " and " insoluble " calcium and magnesium, sulphates and carbonates, failed to reveal appreciable change in the condition of the water, and it is concluded that the process causes no considerable reduction in the resultant salts, either as combined salts or in the " ionic " state.

Theta Tubing. ANON. (*Amer. Mach.*, xxxvi, 14, 551.)—Jacobs's theta tubing is a special-shaped tube, which combines maximum strength with minimum weight. Very desirable qualities for bicycle and motorcycle frames, aëroplane frames, and other light vehicles, which require more strength than the present round tubing affords. Theta tubing is so-called because its cross-sectioned shape resembles the Greek letter θ. The tubes are made of sheet alloy steel, which, when oil treated, has its tensile strength increased by 60 to 75 per cent. Two sheets are bent over mandrels to approximately the required shape and then welded together; the surfaces are then ground on an emery wheel, making the welded portion as smooth as the rest of the tube. A machine is being designed to roll this tubing out of flat sheets, and another for welding the tubing. This tubing was invented by H. W. Jacobs, assistant superintendent of motive power of the Atchison, Topeka and Santa Fe Railway, and is made by the Air Light Metal Company, Atchison, Kan.

The Behavior of Anomalous Dielectrics. H. JORDAN. (*Deutsch. Phys. Gesell. Verh.*, xiv, 9, 451.)—In this paper the behavior of dielectrics with constant and variable applied voltages is fully investigated. The method of von Schweidler is applied to this investigation, the dielectric forming part of a plate condenser. The rate of charge and discharge with respect to time of a practical condenser charged with a steady pressure differs from the theoretical condenser. The divergence is fully investigated, the condensers used being the ordinary telephone type paper-tinfoil condensers. These condensers were found unsuitable for alternating-current measurements, as they behaved exactly like a cable with the distant end open-circuited. This difficulty was obviated by unwinding the condensers and using such a small portion that it operated as a condenser and the cable effect was no longer evident. The direct-current measurements were taken by means of a continuously revolving commutator arranged to charge the condensers for a definite fraction of a revolution and to discharge for the rest of the cycle, the discharge current being measured at different times of the discharge period by means of a ballistic galvanometer. For the alternating current tests a commercial alternator ($w = 2\pi n = 314$), a small, high-frequency Siemens and Halske generator ($w = 4{,}000$ to $10{,}000$), and for higher frequencies a Poulsen generator, were used. The measurements were effected by the bridge method. The results are plotted in curves, and the original paper should be referred to, as these are not easily abstracted.

Weak Solutions of Radium. H. W. SCHMIDT and H. NICK. (*Phys. Zeitschr.*, xiii, 199.)—The best methods for making standard measurements of radium by the emanation method are described. It has generally been thought that the emanation evolved from weak radium solutions diminishes with time, owing to a supposed absorption of radium by the glass. The authors find no effect of this kind with hydrochloric acid solutions of pure radium or of radium and barium salts. The currents in absolute e. s. units produced per Curie of emanation in various cylindrical ionization chambers were measured and found in good agreement with the values calculated from the empirical formulæ of Duane and Laborde.

Mechanical Model of an Electron. U. CISOTTI. (*N. Cimento*, 2 Ser. vi, 375.)—Beside the rigid electron of Abraham, and the deformable electrons of Lorentz, Bucherer and Langevin, he considers an elastic sphere moving in an infinite liquid and deformed by the pressure of the liquid on its surface. Hence the sphere will become an ellipsoid with its minor axis in the direction of motion. The shortening of the minor axis and the lengthening of the equatorial axis are both proportional to the square of the velocity, and so is the increase of volume.

Change of the Dielectric Constant of Rubber upon the Application of a Tensile Stress Perpendicular to the Lines of Force. L. SCHILLER. (*Ann. Phys.*, xxxv, 931.)—The dielectric constant of a rubber plate was measured by determining the capacity of a condenser formed by the plate and two adjacent metal sheets. The capacity of this condenser was compared with a similar condenser made from a sheet of material of the same thickness and of known dielectric constant. Preliminary experiments show that, in accordance with the general assumption, rubber undergoes deformation without volumetric change, and that its Poisson constant is the same in different directions. The dielectric constant of the rubber decreased when it was stretched in a direction perpendicular to the lines of force; with 30 per cent. elongation the constant decreased from 3.67 to 3.51. The application of the Wiener theory of the dielectric constant of mixtures leads to the conclusion that a state of deformation cannot consist entirely in the anisotropy of the arrangement of molecules which are themselves unchanged. Rather it is to be assumed either that the molecules are stretched in the direction of the tensile stress, or that the molecules, which are already elongated and isotropically arranged, place themselves with their longer axis in the direction of stress.

Volcanoes of Central Madagascar. A. LACROIX. (*Compt. Rend.*, cliv, 476.)—The lavas are of two types, the predominant one being a basaltic series, the other a trachyte series. The former varies from a feldspathic basalt to a melilite; the latter consists of hornblende-rhyolite, biotite-trachyte, riebeckite, phonolite-trachyte, and, finally, phonolite. The theory of the age and the succession of the above lavas is thoroughly discussed.

Influence of Flame Temperature on Incandescence Gas Light. H. STRACH. (*J. Gasbeleucht*, lv, 445.)—The candle-power of upright and inverted incandescence burners was measured with gas containing varying amounts of carbon dioxide. Coal gas containing some carburetted water gas was used. For each series of tests the gas was stored in a holder and mixed with varying quantities of carbon dioxide, and the gross calorific value was determined. In each case the burner was adjusted to give the best effect. With an upright burner the number of calories required per candle-power was 5.78 with gas free from carbon dioxide, 5.71 with gas containing 3.8 per cent., 7.46 with gas containing 11.2 per cent., and 9.85 calories with 21.0 per cent. of carbon dioxide. Similar results were obtained with an inverted burner and with gas enriched with petroleum spirit or acetylene so as to have the same calorific power after the addition of the carbon dioxide. The decrease in the efficiency is due to the fact that gas containing carbon dioxide burns with a larger flame which has a lower temperature.

Increase in Mid-Continent Oil. KANSAS AND OKLAHOMA PETROLEUM PRODUCTION GREATER BY 3,000,000 BARRELS IN 1911 THAN IN 1910, ACCORDING TO UNITED STATES GEOLOGICAL SURVEY. —At least 56,000,000 barrels of oil produced in the Kansas-Oklahoma oil field in 1911 is the estimate of David T. Day, of the United States Geological Survey, against an output of 53,157,386 barrels in 1910. In the Barnsdell and Sinclair pools, in Osage County, Okla., wells of 1,000 to 3,000 barrels daily yield were brought in with sufficient frequency during the year to keep the production of the pool in the neighborhood of 20,000 barrels a day, with a gradual decline toward the end of the year. This new production, together with the increase in the Hogshooter and Pawnee County pools, pushed the output beyond the record in 1910, in spite of the great drought in June and July, which was so severe as to drain the drinking supply of several towns and interfere greatly not only with drilling but with manufacturing enterprises. Several times during the year stocks were drawn upon to slight extent, and increased prices for the oil resulted. Transportation facilities were increased by an 18-inch line built by the Prairie Oil and Gas Company from Turley west twenty miles to Osage Junction. Another 18-inch line was built by the same company from Osage Junction to Cherokee, thirty miles to the northeast. The Texas and Gulf companies also ran lines connecting the Osage pools.

Treatment of Water with Chlorine. J. RACE, F.I.C. (*Jour. Soc. Chem. Ind.*, xxxi, No. 13, 611.)—The use of chlorine as a disinfectant developed entirely within the nineteenth century, immediately after the commercial production of bleaching powder. It was used early in the century for the disinfection of sewage and water, and in 1854 its efficiency was so well recognized that an English royal commission recommended its use for deodorizing the sewage of London. Later it was in practical use in many places in England, Germany, and the United States. Sometimes it is added to the unfiltered water, but that method is wasteful, and there is no doubt that if chlorine is to be employed to the fullest advantage it should be added to the filter effluents. The turbidity, color, and organic impurities of a raw water are not apparently reduced by chlorine, but they are acted upon, with a consequent loss of available disinfectant. The disadvantages of adding chlorine to unfiltered water may be summarized thus: With mechanical filters: Reduced efficiency of chlorine. Slow sand filters: Reduced efficiency of chlorine, and reduced purification by the filters *per se*. When present in water in amounts exceeding one part per million of available chlorine, it can generally be detected by the senses. The taste of chlorine is sharp and acid, and the odor pungent, but these should not be confounded with the sensory characteristics of natural untreated water. Chlorine tends to increase the corrosive properties of water, but in very small amounts this effect is inappreciable.

Exhaust Gas Calorimeter for Internal Combustion Engines. J. S. NICHOLSON and T. B. MORLEY. (*Engin.*, xciii, 721.)—The calorimetric method of measuring the heat contained in the exhaust gases of internal combustion engines, which was adopted by the committee of the Institution of Civil Engineers investigating the efficiency of these engines, is considered unsatisfactory, because the hot gases were mixed with the cooling water. An improved calorimeter is described and illustrated in two forms, which has been used in the James Watt Engineering Laboratories of Glasgow University for about four years with satisfactory results. It is built up of standard pipe fittings; its main principle is that the water and gases are kept separate. The gases flow through a length of Serve tubing, which is surrounded by a pipe of slightly larger diameter, and water is forced through the small concentric space, in a direction opposite to the flow of gas. Thermometers are inserted at suitable places, and the fall of temperature between two thermometers is easily seen. The final temperature of the water and the rate of supply are measured, and the final temperature of the cooled gas, which is compared with the atmosphere.

Nitrates from the Atmosphere. E. K. SCOTT. (*J. Roy. Soc. Arts,* lx, 654.)—This is an account of the progress and present position of the manufacture of nitrogen compounds from atmospheric nitrogen. It is stated that the installations now working the Birkeland-Eyde process have a capacity of 200,000 horsepower, while it is estimated than a further 300,000 horsepower will be at work by 1916. In this process it has been found possible to reduce the size of the absorption towers for the nitrogen peroxide to about one-half by using special earthenware packing instead of pieces of quartz. With regard to calcium cyanimide (nitrolim), the works now in operation and being built have a capacity of over 250,000 tons per annum. Owing to the lack of cheap electrical power this industry has no footing in the United Kingdom.

Determination of Radium in Rocks and Minerals. E. EBLER. (*Chem. Zeit.,* xxxvi, 604.)—The substance is freed from radium emanation by fusion, either alone or with a suitable flux, in a platinum boat, and is then allowed to remain for a definite period, 2 to 30 days, in a closed quartz tube, from which the gaseous contents are ultimately pumped into a gasometer, the material being again fused. From the gasometer the gases are transferred to an exhausted ionization chamber, and the quantity of emanation is determined in the usual way, the amount of radium being found by a comparative experiment with the emanation from a known quantity of radium. Standards may be prepared from radium-barium salts, preferably the oxalates, by carrying out a relative atomic weight determination, by observing the loss of weight on ignition, using a micro-balance.

The Fibre of the Baobab Tree for Paper Making. J. S. Remington, D. A. Bowack, T. P. Heald, and A. Davis. (*Aynsome Annual,* iii, 62.)—Paper-making trials on a small scale were conducted with the separated bast of the *Adansonia digitata,* or Baobab tree. The commercial bast consists of strips of yellowish-red, interlaced fibrous tissue, clean and well prepared, free from adherent woody matter, and varying in length from 3 to 6 feet. An analysis showed 56.96 per cent. of cellulose, the length of the ultimate fibres ranging from 2.6 to 5.1 mm.: average, 3.6 mm.; the ash was 6.92 per cent. The material is only very slightly lignified, but is rich in pectic matters. The ultimate fibres are smooth, tapered, and rather thin walled, like those of Manila hemp, but broaden out toward the middle in a characteristic manner, sometimes becoming flattened and twisted. The cellulose is separated by a fairly mild treatment, a proportion of 5 per cent. of sodium hydroxide being sufficient, provided a pressure of 5 to 7 atmospheres be employed. Using 7 per cent. of caustic soda, the material yielded 47.5 per cent. of pulp, which was readily bleached by 14 per cent. of bleaching powder, giving a final yield of 42 per cent. of bleached pulp. A digestion by the bisulphite process yielded 44 per cent. of bleached cellulose. These trials showed that the Adansonia fibre is a very valuable material. It readily works "wet" and it blends well with sulphite wood-pulp, imparting strength, rattle, and length of pull; it should be an excellent raw material for tissue papers. The price of the raw bast is somewhat high, but if the sources of supply were more fully developed, it should be brought within practicable limits.

A Naval Architect on Safe Ships. Anon. (*Sci. Amer.,* cvi, 22, 491.)—Otto Kretschmer, Dean of the Marine Engineering Department of the Charlottenburg Technical High School, has drawn attention to his plans for an unsinkable transatlantic ship. This embodies the principle of constructing a hull within a hull. The inner body, which is entirely independent of the outer, contains all the engines and boilers, and it is walled in with steel plating, through which there are no communicating doors between the outer and inner structures. This, as we have shown in these columns, is the only principle of construction on which a practically unsinkable ship can be built.

Burning Pulverized Coal in Smelters and Furnaces. L. S. Hughes. (*Min. and Eng. World,* April 20, 1912.)—The great drawback to the use of pulverized coal is the damage produced by the formation of a vitrous coating or clinker upon the grate bars, crown sheet, and walls of the firebox, due to the combination of iron oxide with the silica in the coal ash. This production of clinker can be avoided by mixing limestone with the fuel, in a quantity approximately equal to the weight of the coal ash. The mixture is fed into the furnace by a simple air-blast injector.

Volatility of the Platinum Group of Metals. Sir W. Crookes. (*Roy. Soc. Proc.* A lxxxvi, 461.)—In an electrical resistance furnace, formed of a close helix of platinum strip around a porcelain tube, it was found that the strip thinned and ultimately melted, and on the porcelain tube at the point of rupture a deposit always occurred which consisted of microscopic, hexagonal crystals of platinum. This led to an investigation of the volatility of platinum and its congeners at temperatures below their melting points. The metals were heated in the electric furnace to 1300° C. for successive periods of two hours. The loss of weight was approximately proportioned to the time of heating, and in 30 hours amounted to 0.245 per cent. of its weight for platinum, to 0.745 per cent. for palladium; in 22 hours, to 7.297 per cent. for iridium, and in 30 hours to 0.131 per cent. of rhodium, while ruthenium lost 25 per cent. in 8 hours. With iridium, the amount of loss for equal periods of heating, at temperatures between 1100° C. and 1400° C., increased proportionately to the rise of temperature. After these exposures at 1300° C. the platinum had not sensibly changed in appearance, the palladium gradually lost its smoothness and became crystalline and *moiré,* the iridium showed the same change to a greater degree, the rhodium slightly darkened, but did not become crystalline, and the ruthenium became dull black and was coated with oxide. On repeating the experiments at 900° C. with a Méker burner, these changes only occurred to a very slight degree. In the case of ruthenium, there is no doubt that the volatility is due to the formation of oxide, and probably so in the case of iridium, for a quantity heated to 1300° C. for 30 hours in a quartz tube *in vacuo* lost only 0.069 per cent. Platinum and rhodium, however, appear to volatilize as metal.

The Lohmann Coating for Iron. Anon. (*Met. and Chem. Engin.,* x, 253.)—The Lohmann process, adopted by the Brier Hill Steel Company, of Youngstown, Ohio, resembles the old, hot, galvanizing process. The metal is pickled in sulphuric acid and then passed into the Lohmann bath, which contains hydrochloric acid, mercury bichloride, and ammonium chloride. The dried metal is afterwards immersed in the fused alloy; the mercury is stated to volatilize, and the alloy enters the pores thus formed. Zinc, lead, and alloys of these two metals, with or without tin, are said to adhere well.

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THE PROGRESS IN TESTING FULL-SIZE PIECES UNDER PRACTICAL CONDITIONS, TOGETHER WITH LOCOMOTIVE TESTING IN THE UNITED STATES.[1]

BY

PROF. GAETANO LANZA

The Baldwin Locomotive Works, Philadelphia

IN the "Proceedings of the American Society for Testing Materials," for 1904, appeared an article by the author, entitled "A Brief Review of the Status of Testing in the United States." In that article two periods were considered, the second of which began shortly after 1875, or about the time when the Emery testing machine of 800,000 pounds capacity was constructed for, and installed at, the Watertown Arsenal. This second period was marked by the constantly-increasing recognition of the fact that the engineer needs the results of testing full-size pieces under practical conditions, in order to know what constants to use when making designs of structures and machines, and in order to verify or to disprove the theoretical considerations upon

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[1] Presented at the meeting of the Mechanical and Engineering Section held Thursday, October 10, 1912, based on a paper of the same title presented by the author at the Sixth Congress of the International Association for Testing Materials.

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which his calculations are based, or how to modify them. The tests of this second period were, in that paper, classified as:

1. Tests for the purpose of securing good material and reasonable specifications.

2. Tests of full-size pieces, under practical conditions.

3. Investigations made for the purpose of ascertaining the laws of variation of the different properties of a substance.

With the first of these classes, though it is all-important and although the American Society for Testing Materials has devoted to it the greater part of its energies and has already accomplished most valuable and important results, the present paper will not deal—its object being to outline the progress made in and the present status of the second class.

In order to explain the importance of testing full-size pieces, a few illustrations will be given, as follows:

(*a*) In full-size eyebars, the tensile strength is always less per square inch than that of a small sample of the same steel.

(*b*) In steel columns, whether built up as in bridges or solid as in connecting rods of locomotives, no tests of small samples will show the strength.

(*c*) In timber beams or columns, there are always knots, cracks, crooked grain, or other defects, in the full-size member which are not allowed to be in the small sample, and they exert the greatest influence on the strength on the full-size piece.

(*d*) In cases where there are complicated stresses, full-size tests are needed to determine the strength of the specimens.

In the early days the limitations to the capacities of the testing machines in use precluded the possibility of the second class of investigations, and hence it is that the development of such tests must necessarily go hand in hand with the growth in capacity of the machines—the recognition of the need for their results leading to the construction of more powerful ones, and their possession rendering possible the making of the experiments.

While transverse tests of some full-size pieces can be performed by means of machines of a capacity of 100,000 pounds, and sometimes of less, tensile and compression tests of full-size pieces are practically impossible with machines of less than 300,000 pounds, and many without those of far greater capacity.

Almost all the powerful testing machines in the United States, except that at Phœnixville and that at Ambridge, Pa., are either

"Emery," "Olsen," or "Riehle" machines. The writer, therefore, secured from the makers lists of all the machines of their manufacture in use in the United States, of 300,000 pounds capacity and upwards, to determine which establishments have the necessary equipment for making such tests. By communicating with them and with others the author has endeavored to ascertain what full-size testing has been, and is being, performed in this country and the nature of the results obtained.

In the light of this information, which, though not assumed to be complete, is quite comprehensive, he will endeavor to present here the general situation at the present time.

A study of the information thus obtained makes it evident that the testing of full-size pieces, in the United States, has developed enormously since the year 1875, and that powerful testing machines are now in the possession of the laboratories of many industrial concerns, such as steel works, bridge-building works, railroads, testing laboratories; also of engineering schools, including experiment stations and of others.

The work done with the aid of these machines may be classified as follows, viz.:

(1) Investigations made for the general good, most of which have been published and are available to all engineers.

(2) Work performed primarily for the benefit of the concerns making the experiments, but which is of such a nature that they have no object in keeping it secret. Most of this has also been published, and is likewise available.

(3) Work done for the purpose of solving some of the problems that arise in connection with the business of the firm, the results of which they do not wish to impart to their competitors.

In the first class are included the results obtained by the Government laboratories and by the engineering schools. The existence of the second and of the third class makes it evident that many large concerns find it not only to their advantage, but also necessary, to be equipped with powerful testing machines in order to solve problems affecting their business.

In attempting a brief review of the situation up to and at the present time, we find that a large amount of work of this character has been carried on by the following Government laboratories:

(1) The Bureau of Standards of the Department of Commerce and Labor.

(2) The Watertown Arsenal of the Ordnance Department, *i.e.,* of the War Department.

(3) The Agricultural Department.

(4) The Geological Survey of the Interior Department.

If we consider this work chronologically, we have:

(1) That at the Watertown Arsenal.

The installation of the well-known Emery testing machine of 800,000 pounds capacity, soon after 1875, gave it a long lead in the matter of full-size testing, and it continued to perform such work throughout a period when the facilities elsewhere were few, and when the need was not as fully recognized as to-day. It is not surprising even now to find that the sum total of such work done by that machine is very large and that the results have excited a great deal of influence upon engineering practice. Among the lines of investigation carried on, of which the results may be found in the reports of the Ordnance Department, entitled "Tests of Metals" covering a period from 1880 to 1905, may be mentioned:

(1) Tensile strength of large eyebars.

(2) Tensile strength of large wire and other ropes.

(3) Tensile strength of riveted joints with six or more rivets.

(4) Tensile strength of riveted and pin connections.

(5) Compressive strength of wrought-iron and steel columns.

(6) Compressive strength of cast-iron columns.

(7) Compressive strength of plain and built-up timber columns.

(8) Compressive strength of columns of reënforced concrete of a great many kinds.

(9) Compressive strength of masonry piers.

(10) Compressive strength of large specimens of stone.

(11) Investigations of the causes of defective rails.

(12) Investigations of the effects of repeated stress upon metals.

(13) Many tests upon the strength and other properties of metals for ordnance purposes.

The above is only a brief and partial list.

Besides the tests made for the general good, many were made for private firms, the results of which, as a rule, have not been published. Each of the classes enumerated might be divided into many sub-classes; thus No. 8 includes a very long and detailed investigation of the effects of different kinds of reënforcement; and this and No. 9 furnish the means of comparing strength and other resisting properties of reënforced concrete with those of masonry.

Many properties of concrete were also studied, among them being the effects of high temperatures.

Under No. 11 investigations were made of the steel from different parts of the ingot, and of the defects in the ingot itself. Tests were also made upon the effects of high temperatures upon steel and upon riveted joints.

(2) Next in order chronologically comes the work done by the Bureau of Forestry, of the Department of Agriculture, upon the strength of full-size pieces of timber. This series of tests was begun about 1903. (A former series of timber tests by the same bureau was mostly concerned with the tests of small pieces.)

The kinds of timbers tested have been mainly the following:

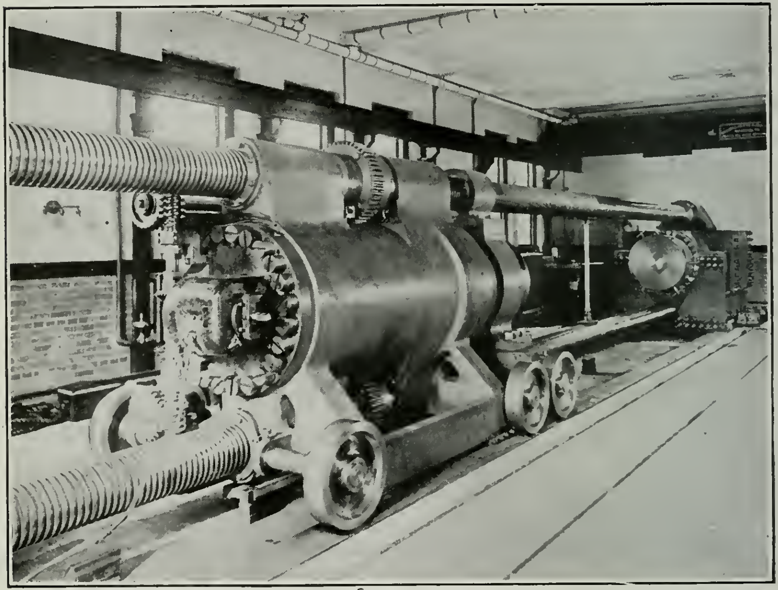
(*a*) Loblolly pine.
(*b*) Long-leaf pine.
(*c*) Short-leaf pine.
(*d*) Douglas fir.
(*e*) Western larch.
(*f*) Tamarack.
(*g*) Western hemlock.
(*h*) Redwood.

(3) The other Government department which is doing work of this character is the Bureau of Standards of the Department of Commerce and Labor, and this, moreover, is the bureau to which we must look principally in the future for results of this class of investigations.

While it is only during the last three or four years that it has undertaken the testing of the strength of materials on an extensive scale, one Emery testing machine for it is already built and another is nearing completion. The latter has a capacity of 2,300,000 pounds in compression and 1,115,000 pounds in tension. This machine is shown in Fig. 1. Besides these, the Bureau already has a number of other machines. Moreover, the laboratories formerly under the direction of the Geological Survey, which devoted the greater part of their energies to tests of concrete and reënforced concrete, have been transferred to the Bureau of Standards, thus adding to their equipment a considerable number of Olsen and Riehle machines, the largest one being an Olsen machine of 10,000,000 pounds capacity.

The Bureau has, for some time, been engaged in making strain measurements upon structures in various parts of the United States. These measurements have been made upon: (*a*) Bridges, (*b*) buildings, (*c*) street pavements, and (*d*) boilers, and embrace also the lock gates of the Panama Canal.

FIG. 1.



Emery testing machine at the Government Bureau of Standards.

The Bureau is arranging for tests upon full-size built-up columns of steel.

Tests are also being made in regard to steel rails.

(4) As to the work done by the Geological Survey, the results have been published by the Bureau of Standards.

The chief laboratory was erected and operated at the grounds of the St. Louis Exposition of 1904. It was mostly concerned with concrete and reënforced concrete, and, while the tests were under the direction of the Geological Survey, they were done with the collaboration of the Joint Committee on Reënforced Concrete. This work dealt especially with reënforced concrete beams, but included a great deal upon concrete and also upon cement and mortar.

Passing next to the steel and bridge works, we find that the two machines of the greatest capacity owned by any of them are:

(*a*) The testing machine of the Phœnix Bridge Company, of 2,400,000 pounds capacity, for either tension or compression, located at Phœnixville, Pa. This machine is shown in Fig. 2.

(*b*) The testing machine of the American Bridge Company, of 4,000,000 pounds capacity, for tension only, located at Ambridge, Pa.

The Phœnixville machine was built in 1864, and was at first employed mostly in the testing of full-size eyebars for the principal railroads, manufacturers and consulting engineers; also of eyebars built up of plates for the larger New York bridges. This machine has tested eyebars of nickel steel having a cross section of 18 inches by 2 inches.

Later, many tests upon full-size compression members were made for various railroads and others, a number of them involving a special study of the action of the pin plates, rivets, and other details.

Recently, more than 50 tests of compression members, both of nickel and of carbon steel, have been performed, including studies of the movement of the material, action of rivets, pin bearings, and other details. A great many tests have been made of tension joints and of tension members for bridges; also about twenty tests of small-size models of large compression members for the Quebec Bridge.

The Ambridge testing machine was built in 1904, from designs of Mr. James Christie. Its capacity is 4,000,000 pounds, while the greatest load that it has sustained was 3,500,000 pounds in testing vanadium steel yokes for the lock gates of the Panama Canal.

This 4,000,000-pound machine had tested, up to May 17, 1912, 1,750 eyebars, all except 166 having been manufactured at Ambridge, the latter tests having been made for the Virginia Bridge Company. Also, 250 tests were made on beams, castings, couplers, etc.

The Ambridge plant has forged and tested eyebars for the following manufacturers:

The McClintic-Marshall Construction Company.
Pennsylvania Steel Company.
Baltimore Bridge Company.
Canadian Bridge Company.
Virginia Bridge Company.
Penn Bridge Company.
Mt. Vernon Bridge Company.
Bellefontaine Bridge Company.
Central States Bridge Company.
Joliet Bridge and Iron Company.
Midland Bridge Company.
Northwest Steel Company.
Louisville Bridge Company.
Bucyrus Company.
American Locomotive Company.
Guerber Engineering Company.
Vanadium Steel Company (experimental tests).

It has also forged and tested eyebars for almost every large railroad in the United States, and for railroads in Japan, Korea, China, South America, Mexico, and Canada.

The following steel works are equipped with testing machines of 600,000 pounds capacity, of either the Olsen or Riehle type:

1. American Steel and Wire Company
2. Pressed Steel Car Company

The following with one of 500,000 pounds capacity, viz.:

3. Scullin, Gallagher Iron and Steel Company

The following with machines of 400,000 pounds capacity:

4. American Steel Foundries Company
5. Bethlehem Steel Company
6. Carnegie Steel Company, Pittsburgh, Pa.
   Carnegie Steel Company, Charlton, Pa.
   Carnegie Steel Company, Munhall, Pa.
7. Midvale Steel Company
8. Johnson Company
9. Jones & Laughlin
10. Inland Steel Company
11. Lorain Steel Company
12. McConway & Torley Company
13. Republic Iron and Steel Company
14. Worth Brothers

Many steel companies are equipped with testing machines of 300,000 pounds capacity. Before referring to the work that has been performed, I will say that the existence of so many large machines among the steel and bridge works renders evident the fact that machines of large capacity are needed by these firms.

The list given above is compiled from the data provided by the makers of testing machines.

Having received this information from them, I proceeded to write to these and other works, asking what they had done and were doing by way of testing full-size pieces, and while many replied that they made no tests of this kind, except to use the machines in their business, others gave me information which I will attempt to summarize here:

(1) Tests of wire rope.
(2) Tests of full-size bars.
(3) Tests of full-size shapes.
(4) Tests of boiler tubes.
(5) Drop and deflection tests of rails and of axles.
(6) Drop tests of tires.
(7) M. C. B. coupler tests.
(8) Tests of rail joints.

The results of many of the eyebar tests made at Ambridge and Phœnixville, and many of the full-size column tests made at Phœnixville, have been published.

As to the railroads, the following is a summary of the tests cited in the replies which I received:

(1) Atchison, Topeka & Sante Fe Railroad, full-size eyebars made at Ambridge.

(2) Baltimore & Ohio Railroad, which owns a 600,000-pound Olsen machine:

(*a*) Full-size eyebars in the course of inspection.
(*b*) Extensometer tests on bridge members.

An account of the latter is given in a paper by J. E. Greiner in the *Proceedings of the American Society of Civil Engineers.*

(3) Chicago, Burlington & Quincy Railroad, spliced sills, mostly drop tests, the account of which is given in a report of a committee of the Master Car Builders' Association.

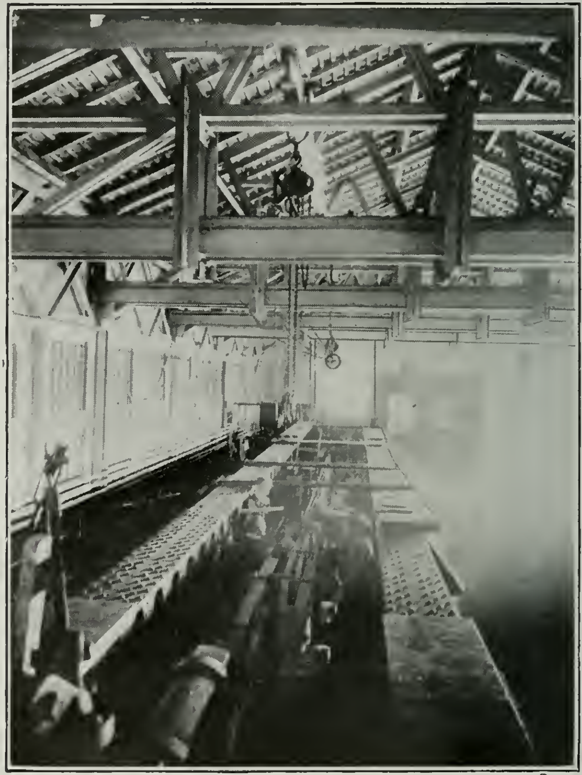
(4) The Chicago, Milwaukee & St. Paul Railroad.

(*a*) Timber stringers by Onward Bates, 1890.

(*b*) Reënforced concrete beams by J. J. Hardy in 1904–1905.

(*c*) Iron pulley blocks at the University of Wisconsin in 1908.

FIG. 2.



Testing machine at the Phœnix Bridge Company.

The tests of Onward Bates were published in the *Proceedings of the American Society of Civil Engineers* and the others in those of the *Western Society of Engineers*.

(5) The New York Central Railroad:
  (*a*) Full-size eyebars.
  (*b*) Full-size cover plate cut from a plate girder in service.
  (*c*) Bending tests of rails.

- (*d*) Air-brake beams, journal boxes, and draft gear.
- (*e*) Axles, couplers, and car wheels by drop tests.
- (*f*) Side frames.

(6) The Pennsylvania Railroad:

- (*a*) Full-size eyebars, reported in *Engineering News.*
- (*b*) Full-size compression members, by C. P. Buchanan.
- (*c*) Full-size compression members, by J. E. Howard and C. P. Buchanan, published in the *Proceedings of the American Society of Civil Engineers.*
- (*d*) Chains and couplers.

The following firms, which were neither steel works nor railroads, replied as follows:

(1) General Electric Company:

- (*a*) Fastening pole pieces to spider in revolving field.
- (*b*) Securing turbine bucket-blades in wheel veins.

(2) Robert W. Hunt Company:

- (*a*) Eyebars.
- (*b*) Brick and reënforced columns.
- (*c*) Reënforced concrete floor studs and panels.

(3) The Pittsburgh Testing Laboratory, which owns a 600,000-pound Olsen machine:

- (*a*) Full-size eyebars.
- (*b*) Inspecting full-size members for the Quebec Bridge.

(4) The Baldwin Locomotive Works, which owns a 600,000-pound Olsen machine:

- (*a*) Equalizer beam.
- (*b*) Full-size bars.

ENGINEERING SCHOOLS AND EXPERIMENT STATIONS.

The following summaries of classes of full-size tests made by various engineering schools have been compiled from the replies received to my letters of inquiry. Even though they may not be complete, they will serve to show the interest taken in, and the part played by, these schools in the making of investigations of this character.

(1) University of Illinois:

Their most powerful testing machine is one of 600,000 pounds capacity. The following is a summary of the kinds of full-size tests mentioned in their reply to my letter of inquiry:

(*a*) Concrete; reënforced concrete beams; reënforced concrete columns.
(*b*) Culvert pipes of reënforced concrete and of cast iron.
(*c*) High-speed tool steels.
(*d*) Resistance of tubes to collapse.
(*e*) Roof trusses.
(*f*) Chain links.
(*g*) Base and bearing plates for columns and beams.
(*h*) Timber beams.
(*k*) Built-up columns.
(*l*) Riveted joints of nickel steel.
(*m*) Holding power of railroad spikes.
(*n*) Brick columns and terra-cotta block columns.

(2) Lehigh University:

Their most powerful testing machine is one of 800,000 pounds capacity. In their reply to my letter of inquiry they cite tests of plain and of reënforced concrete columns.

(3) Massachusetts Institute of Technology:

Their most powerful general testing machine is one of 300,000 pounds capacity, although they have, also, an arch testing machine of 400,000 pounds capacity.

The following is the summary of many of their full-size tests:

(*a*) Tensile tests of
  1. Bolted and riveted joints.
  2. Wire rope.
  3. Cotton, Manila and hemp rope.
  4. Efficiency of knots and hitches.
  5. Concrete.
(*b*) Compressive tests.
  1. Bricks and brick piers.
  2. Wrought-iron pipe columns.
  3. Timber columns, with and without bolsters.
  4. Timber across the grain.
  5. Concrete and reënforced concrete columns (including some at high temperatures).
  6. Cast-iron water pipes.
(*c*) Transverse tests.
  1. Wrought-iron and steel "I" beams.
  2. Masonry arches.
  3. Timber beams.

4. Headers and other framing joints.
5. Splice plates of girders.
6. Granite.
7. Pulley arms and rims.

(*d*) Torsional tests.

1. Wrought-iron shafting.
2. Steel shafting, including cold rolled.
3. Flange couplings.

(4) University of Pennsylvania:

Their most powerful testing machine is one of 600,000 pounds capacity. The following is a summary of the kinds of full-size tests mentioned in their reply to my letter of inquiry.

(*a*) Reënforced concrete beams.
(*b*) Standard "I" beams, Bethlehem "I" beams and girder beams.
(*c*) Concrete piers and columns.
(*d*) Concrete cylinders.
(*e*) Steel columns
(*f*) Concrete arches.

(5) Purdue University:

Their most powerful testing machine is one of 300,000 pounds capacity.

The following is a summary of the kinds of full-size tests mentioned in their reply to my letter of inquiry:

(*a*) Brake beams and car bolsters.
(*b*) Manufactured pieces.
(*c*) Timber beams.

(6) Rensselaer Polytechnic Institute:

Their most powerful testing machine is one of 1,200,000 pounds capacity.

The following is a summary of the kinds of full-size tests mentioned in their reply to my letter of inquiry:

(*a*) Built-up library stacks.
(*b*) Lap joints for gasometers.
(*c*) Cast-steel rail joints.
(*d*) Calibration of dynamometers for dynamometer car.
(*e*) Car couplers.
(*f*) Concrete-filled pipe columns.
(*g*) Fire tests of concrete mixtures.
(*h*) Reënforced concrete beams.

(7) West Virginia University:

Their most powerful testing machine is one of 600,000 pounds capacity.

The full-size tests mentioned in the reply to my letter of inquiry are:

(*a*) Brick and wooden beams.

(8) University of Wisconsin:

Their most powerful machine is one of 600,000 pounds capacity. The following is a summary of the kinds of full-size tests mentioned in their reply to my letter of inquiry:

(*a*) Tests on plain and reënforced concrete, including beams and columns.
(*b*) Tests of reënforced concrete beams.
(*c*) Tests of plain and reënforced concrete columns.
(*d*) Tests of reënforced concrete columns, subjected to repeated and eccentric loads.
(*e*) Tests on bond between concrete and steel in reënforced concrete beams.

The preceding summaries of work of this character done in the United States, though not complete, make evident the enormous progress that has been attained in recent years in the testing of full-size pieces under practical conditions.

LOCOMOTIVE TESTS.

This paper has, thus far, been devoted exclusively to the progress made in the United States in the testing of full-size pieces under the conditions of practice, where the object has been to determine the strength and other resisting properties of the material. In the case of machinery, however, and especially of prime movers and other motors, many other kinds of full-size tests are required, and the making of them is due to the recognition of the same principle that prevails in those already mentioned, viz., that the results obtained by experimenting upon small models, while they may be suggestive and may furnish valuable information, do not take into account all the conditions that exist in the full-size machine or motor, and that it is unsafe to predict its behavior in practice, from the results obtained by such experiments, when a portion of the conditions have been left out of consideration. Any attempt to enumerate the cases where such investigations are needed would be too extensive for any one paper, but a few may be mentioned by way of illustration:

(1) Road tests of locomotives with or without the aid of a dynamometer car.

(2) Stationary tests of locomotives.

(3) Tests of marine motors, whether they employ steam or gasoline as the working fluid, whether they are reciprocating engines or steam turbines, and whether they include or not speed tests and towing tests.

(4) Tests of stationary prime movers, whether they are reciprocating engines or turbines, and whether steam, gas, gasoline, or water be the working fluid.

(5) Power plant tests, including the friction losses throughout the mill or manufactory.

(6) Tests of electric motors.

(7) Tests for balancing high-speed rotative machinery, as dynamos, centrifugal machines, etc.

While there has been a steady increase in the number of tests of this character, nevertheless the principle mentioned above has been recognized for a much longer time than in the case of investigations involving the strength of materials.

In considering the experiments with which we are now dealing, however, the most important development has been the progress made in the attainment of greater scientific accuracy. Thus at the present time plant tests of such short duration as to vitiate the correct determination of the coal consumed are less and less in number and are given less and less credence. Of these various classes the only ones that will be considered here are:

(1) Stationary tests of locomotives.

(2) Road tests of locomotives.

The first are the most recent and the most easily summarized. They are carried on under conditions that can be fully controlled, and furnish a very large amount of most important and valuable information, though, of course, lacking the necessarily variable conditions that exist in road tests.

The development of stationary plants for making locomotive tests, up to the year 1904, has been described in a paper published by Prof. W. F. M. Goss, in the *Proceedings of the*

American Society of Mechanical Engineers for that year. Only a brief summary of what was accomplished up to that time will be given here.

In the paper referred to, Goss mentions:

(1) The early, though rather crude, attempt made in Russia in 1881 and 1882 by Mr. Alexander Borodin.

(2) The first testing plant at Purdue University in 1890.

(3) The plant at Columbia University in 1893.

(4) The temporary plant established at Kakauna by Mr. Robert Quayle in 1893.

(5) The second plant at Purdue University in 1894.

(6) The plant of the Chicago & Northwestern Railroad at Chicago in 1895.

Besides the above he gave a description of the plant of the Pennsylvania Railroad Lines, then being established at the St. Louis Fair.

In the discussion Mr. E. Worthington stated that Mr. Churchward, of England, was imitating the example.

Professor Goss stated that Mr. M. V. Goloboloff, of Russia, was building a plant at the Putiloff Works, at St. Petersburg, Russia.

The work done by these plants up to that time, as explained in the papers referred to, may be summarized as follows:

(1) The work of Mr. Borodin dealt especially with the effects of steam jacketing.

(2) The results obtained by Goss, prior to the fire which destroyed the first plant at Purdue University, were published in two papers presented by him to the *American Society of Mechanical Engineers,* one in 1894 and the other in 1896.

They included: (*a*) efficiency tests; (*b*) studies of counterbalancing; (*c*) studies of the effects of long indicator pipes; (*d*) a study of the differences in the results obtained by running with the throttle wide open or partially closed.

(3) The work done by means of the temporary plant at Kakauna was devoted especially to a study of the action of the front end.

(4) That of the second plant at Purdue University up to 1904, when three locomotives had been made the subjects of experiment, included many investigations, among which were the following:

(*a*) A study of the amount of steam per horse-power per hour required by the locomotive under favorable conditions.

(*b*) Definition of the evaporative performance of the locomotive boiler.

(*c*) Degree of dryness of the steam in the locomotive boiler.

(*d*) Comparison of the results when the locomotive output is controlled by the reverse lever with those when the control is partly by the throttle.

(*e*) Point of most economical cut-off for a simple locomotive.

(*f*) The value of the steam pipes in the smoke-box as a superheater.

(*g*) Action of the steam jet in the production of draft.

(*h*) Study of the losses involved in the emission of sparks.

(*i*) Study of the proportions of exhaust pipes and stacks.

(5) The chief work performed by the plant of the Chicago & Northwestern Railroad at Chicago, up to 1904, was that carried on under the direction of a committee of the *Railway Master Mechanics' Association,* covering exhaust pipes and steam passages, the account of which is published in the proceedings of that society for 1896.

Other work performed by means of this plant was:

(1) Studies of the values of different kinds of coal.

(2) Study of the efficiency of different types at different speeds and cut-offs.

(3) Effects of changes of lead and inside clearance and of defects in design of valve gear.

THE LOCOMOTIVE TESTING PLANT OF THE PENNSYLVANIA RAILROAD.

This plant, which is the finest in the country, was designed by Mr. A. S. Vogt, then mechanical engineer of the railroad; the plans were begun in 1903, and the first locomotive was placed upon it on May 25, 1904.

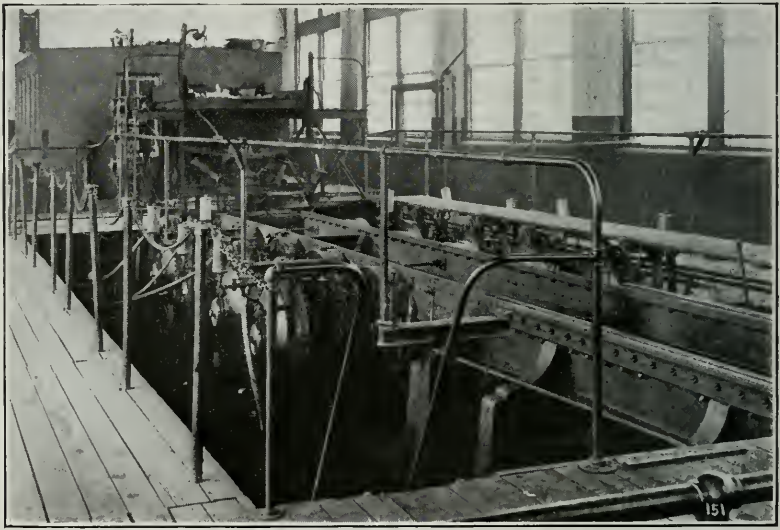
It was first located at the grounds of the St. Louis Exposition, during the time of the World's Fair held in that city in 1904:

and was afterwards transferred to its permanent position at Altoona, Pa.

Fig. 3 is a general view of this plant, with no locomotive on it. Fig. 4 shows the housing of the dynamometer. In Fig. 5 is shown a locomotive in position.

A very complete and fully-illustrated description and account of what was accomplished with it while at St. Louis has been published in book form by the Pennsylvania Railroad.

FIG. 3.



Locomotive testing plant, Pennsylvania Railroad. General view.

These tests were very complete, and included, as nearly as possible, the entire range of conditions of service. Eight locomotives were tested, of which four were freight and four passenger engines.

Of the freight locomotives three were simple engines, of the consolidation (2–8–0) type, with their total weights and their weights on drivers approximately equal.

These three were:

(*a*) A simple consolidation (2–8–0), owned by the Pennsylvania Railroad, and numbered 1499:

Total weight	194,200 pounds
Weight on drivers	173,000 pounds

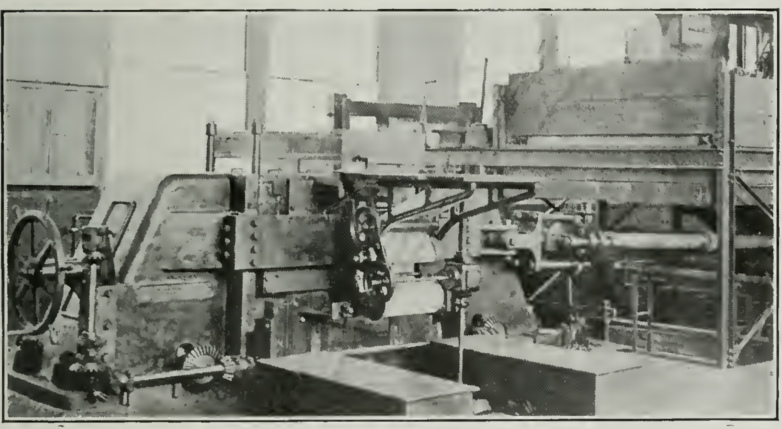
(*b*) A simple consolidation (2–8–0) owned by the Lake Shore & Michigan Southern Railroad, built at the Brooks Locomotive Works, and numbered 734:

Total weight	181,300 pounds
Weight on drivers	162,600 pounds

(*c*) A two-cylinder cross-compound consolidation (2–8–0) owned by the Michigan Central Railroad, built at Schenectady by the American Locomotive Company, and numbered 585:

Total weight	189,000 pounds
Weight on drivers	164,500 pounds

FIG. 4.



Locomotive testing plant, Pennsylvania Railroad. Dynamometer housing.

The fourth freight locomotive was:

(*d*) A four-cylinder tandem compound Sante Fe (2–10–2) owned by the Atchison, Topeka & Sante Fe Railroad, built at the Baldwin Locomotive Works, and numbered 929:

Total weight	285,740 pounds
Weight on drivers	233,760 pounds

The four-passenger locomotives were all four-cylinder, balanced compound locomotives of the Atlantic (4–4–2) type. Two were built in the United States, one in Germany and one in France.

(*e*) A Vauclain four-cylinder, balanced compound Atlantic type (4–4–2), owned by the Atchison, Topeka & Santa Fe Railroad, built by the Baldwin Locomotive Works, and numbered 535:

Total weight	201,500 pounds
Weight on drivers	99,200 pounds

(*f*) A Cole four-cylinder, balanced compound Atlantic type (4–4–2), owned by the New York Central Railroad, built at Schenectady by the American Locomotive Company, and numbered 3000:

Total weight	200,000 pounds
Weight on drivers	110,000 pounds

(*g*) A four-cylinder, balanced compound Atlantic type (4–4–2), provided with a Pielock superheater, built by the Hanoverische Maschinen Gesellschaft of Hanover, Germany, presented by them for test, and numbered 628:

Total weight	133,350 pounds
Weight on drivers	65,350 pounds

(*h*) A De Glehn four-cylinder, balanced compound Atlantic type (4–4–2), owned by the Pennsylvania Railroad, built by the Société Alsacienne de Constructions at Belfort, France, and numbered 2512:

Total weight	164,000 pounds
Weight on drivers	87,850 pounds

The chief purpose of the tests, as stated in the programme, was " to establish with accuracy the actual performance of certain typical locomotives."

In carrying this out, a careful study was made both of the boiler and of the engine performance, including:

(1) A study of the efficiency of the boiler under the various conditions of running.

(2) A study of the capacity of the boiler.

(3) The relative advantages of small and of large grates.

(4) A study of the furnace losses.

(5) A study of the temperatures in the fire-box and in the smoke-box.

(6) A study of the draft in the ash-pan, in the fire-box, and in the smoke-box.

(7) A study of the relation between the CO formed and the temperature in the fire-box.

(8) A study of the advantages of throttling as compared with running with the throttle wide open and regulating by the cut-off.

(9) A study of the effects of the brick arch.

(10) A study of the losses due to imperfect combustion and those due to excess of air, and many other features concerning the boiler.

(11) A study of the horse-power developed by freight engines and that by passenger engines.

(12) A study of the maximum tractive effort at different speeds.

(13) A study of the steam consumption per horse-power per hour at different speeds and cut-offs.

(14) A study of the relative economy of compound as compared with simple locomotives when developing different horse-powers.

(15) A study of the per cent. of cylinder power realized at the drawbar.

(16) A study of the effect of using greases for lubrication as compared with the use of oil.

(17) A study of the various vibrations, as jerking, pounding, nosing, and other features.

After the plant was moved to Altoona another locomotive was tested in the same manner as those at St. Louis, viz.:

A simple locomotive of the Atlantic type (4–4–2), owned by the Pennsylvania Railroad, and numbered 5266:

Total weight	184,167 pounds
Weight on drivers	110,001 pounds

Besides the above, the following, among other investigations, have been made by means of this plant:

(1) A series of tests of briquettes made by the United States Geological Survey from a low volatile or semi-bituminous coal.

(2) Tests of a fire-door with enlarged air-admission openings and a deflector.

(3) Tests of various coals.

(4) Tests of a hollow fire-brick arch.

(5) Tests of the result of varying grate area.

(6) Tests of a fire-kindler.

(7) Tests of a self-cleaning front end.

(8) Tests of an E–2–d locomotive.

(9) Tests of the regular level method of firing as compared with the bank method.

(10) Tests of a Baldwin superheater.

(11) Tests of the effects of cylinder drainage.

(12) Tests of the throttling as compared with regulating by reverse lever.

(13) Tests of the Parsons combustion system.

(14) Tests of a coal with little volatile matter.

(15) Tests of the Jones stoker.

(16) Tests of a special grate.

(17) Tests to determine the increase, if any, of the coal burned due to blowing the air-pump exhaust through the stack.

(18) Tests of lubricators.

(19) Tests of a K–2 Class locomotive, No. 7510.

(20) Tests of Baker Pilliod valve gear.

ROAD TESTS.

Road tests of locomotives were made on many railroads long before stationary plants were ever thought of. The principal development along these lines has been the tendency to take more care, in order to avoid obtaining apparent results that are misleading.

Many difficulties have to be overcome that do not arise in stationary tests, as already explained. On the other hand, it is precisely the performance of the locomotive under the variable conditions that arise in practice that the railroad man needs most to know.

Only a few of the precautions that ought to be carefully observed will be mentioned here:

(*a*) The coal or other fuel consumed.

(*b*) The water evaporated.

(*c*) The power developed, both in the cylinders and at the drawbar.

It would therefore seem that, as a matter of course, the person responsible for the test would endeavor to secure accuracy in the determination of these items, and yet many have been made where the necessary precautions have not been taken, and where, consequently, the conclusions have been erroneous.

Commenting upon these items we may observe:

(*a*) In order that reasonable accuracy may be obtained in the determination of the coal consumed, while it is necessary that it be correctly weighed, it is also of great importance that the duration of the test should be of a sufficient length to insure that the unavoidable errors in the estimation of the coal should be only a small percentage of the total amount consumed.

Most tests to-day are made with runs of approximately one hundred miles, and this distance is none too great, as there are often about fifty of the one hundred miles which are down grade, and therefore where the throttle is closed.

(*b*) As to the water evaporated, care should be taken, whatever the method pursued, to determine it correctly, and, of course, the amount of priming, or the amount of superheat in the steam that enters the cylinder, should be correctly determined.

(*c*) As to the power developed:

(1) Indicator cards should be taken with sufficient frequency, and all the cylinders should be separately indicated, as it leads to very erroneous conclusions to indicate only one cylinder of a two-cylinder engine, and to assume that the performance of the other is identical with it.

(2) The only way to determine correctly the power developed at the drawbar is by the use of a good dynamometer car. Some of the larger railroads possess such cars, but there are all too few in use.

(*d*) The speed:

When a dynamometer car is employed, the speed can be best determined from its records, but in doing so we must bear in mind that, if we divide the distance travelled in one five-second period by five, the quotient will express the average speed during that five-second period and not the actual speed at any one instant.

In the same way, if we divide the distance travelled during a longer period, the quotient will express the average speed during that period and not the actual speed at any one instant.

These considerations are of special importance in the case of tests to determine train resistance and its variation with speed.

There are numerous speed recorders, some of which can be made to record fairly well, if sufficient care is taken.

Of course, revolution counters should also be used on the locomotive. Many other precautions need to be taken to secure correct results, but they will not be discussed here.

The form in which the results are presented should be such as to enable the reader to grasp them readily, with their variations, and to make comparisons easily. In this connection, the construction of graphical diagrams, for a part of the summaries, is very important.

It is, moreover, the belief of the writer that if suitable care be taken the percentage of errors can be made sufficiently small for practical purposes, and that good road tests furnish much information that can never be obtained from stationary ones.

Rules for road tests have been laid down by many, including the *American Society of Mechanical Engineers*, the *Railway Master Mechanics' Association*, and by individuals who have conducted many such investigations.

Moreover, it is often the case when a railroad is making a series of tests in order to ascertain some special matter, as a comparison of different kinds of coal or to determine a tonnage rating for some special division of the road, that it would cost but little more, in time, energy, and money, to make the test more complete, and to obtain further information, which, though not serving the immediate purposes, may be very much wanted later. To undertake to give even a partial list of the railroads making road tests, would be beyond the scope of this paper. Hence only two sets of such tests will be mentioned here, by way of illustration, and with the object of explaining the nature of the information sought for from them.

These two series both took place during the past year:

A SERIES OF TESTS MADE ON THE PENNSYLVANIA RAILROAD IN 1911.

The main object was to determine the hauling capacity and the economy of four locomotives, viz.:

(1) No. 5075; a 22 inch by 26 inch (80-inch drivers) Atlantic type (4–4–2), using saturated steam, and hand fired:

Total weight	231,500 pounds
Weight on drivers	133,800 pounds

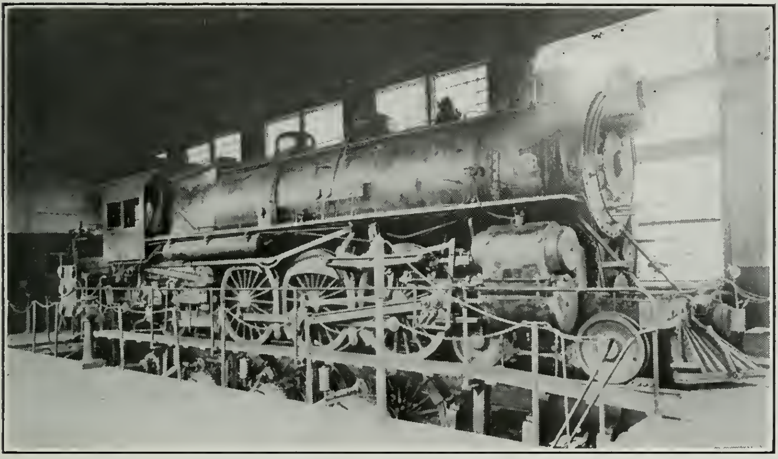
(2) No. 7514; a 24 inch by 26 inch (80-inch drivers) Pacific type (4–6–2), using highly superheated steam, and hand fired:

Total weight	292,000 pounds
Weight on drivers	190,300 pounds

(3) No. 9996; a 24 inch by 26 inch (80-inch drivers) Pacific type (4–6–2), using saturated steam, and stoker fired:

Total weight	272,000 pounds
Weight on drivers	178,500 pounds

Fig. 5.



Locomotive testing plant, Pennsylvania Railroad.

(4) No. 9999; a 24 inch by 26 inch (80-inch drivers) Pacific type (4–6–2), using saturated steam, and hand fired:

Total weight	272,000 pounds
Weight on drivers	178,500 pounds

Fig. 6 shows Locomotive No. 5075. Fig. 7 shows No. 3395, of same type as the other three.

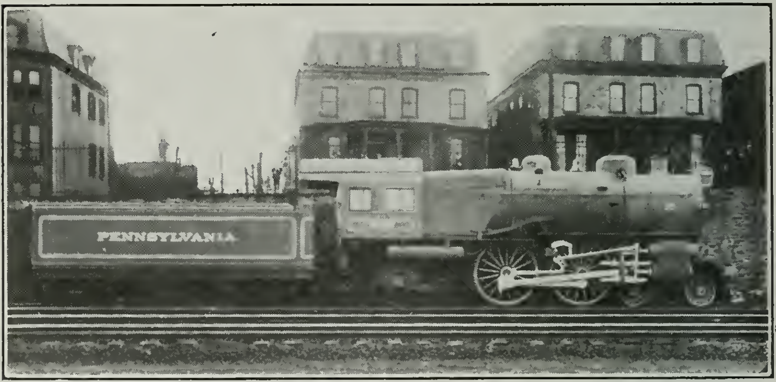
All the runs were made from Fort Wayne to Valparaiso, Ind., a distance of 105 miles. The number of cars used with each engine were 9, 10, 11, 12, 13, and 15, each car loaded weighing about 62 tons.

The coal was weighed and analyzed. The water was measured by a float. The speed was obtained from the records of the dynamometer car, belonging to the Pennsylvania Railroad, and numbered 495,591. Fig. 8 shows the exterior and Fig. 9 the interior of this car. Indicator cards were, in every case, taken from all the cylinders. The drawbar pull was determined from the records of the dynamometer car.

Besides the above, all other records needed in a complete test were taken, as pressures, temperatures, position of reverse lever, opening of throttle, calorimeter readings, draft pressures, etc.

Of the three Pacific type engines, No. 9999 was adopted as a standard of comparison, and the performances of the others were determined in terms of those of 9999. The arrangement of the work was such as to lead to the determination of the following quantities, among others, viz.:

FIG. 6.



Atlantic type locomotive, No. 5075, Pennsylvania Railroad.

(1) The coal consumed.

(2) The water evaporated.

(3) The indicated horse-power and the tractive force of the engine.

(4) The dynamometer horse-power and the drawbar pull.

(5) The running speed.

(6) The temperature and pressure of the steam entering the steam chest.

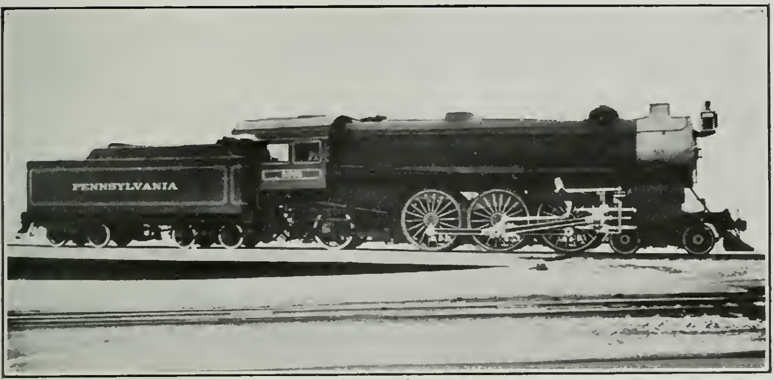
(7) The priming.

(8) The thermal efficiency.

(9) The temperature of the hot gases.

(10) The draft in the fire-box and in the smoke-box.
(11) The amount of smoke.

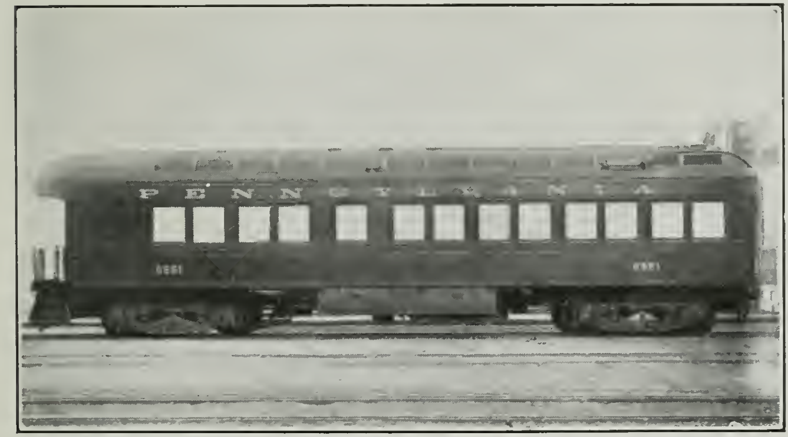
FIG. 7.



Pacific type locomotive, No. 3395, Pennsylvania Railroad.

A study was also made of the effects produced by the use of brick arches and circulating tubes, and many comparisions were made of the results obtained with the four engines respectively.

FIG. 8.



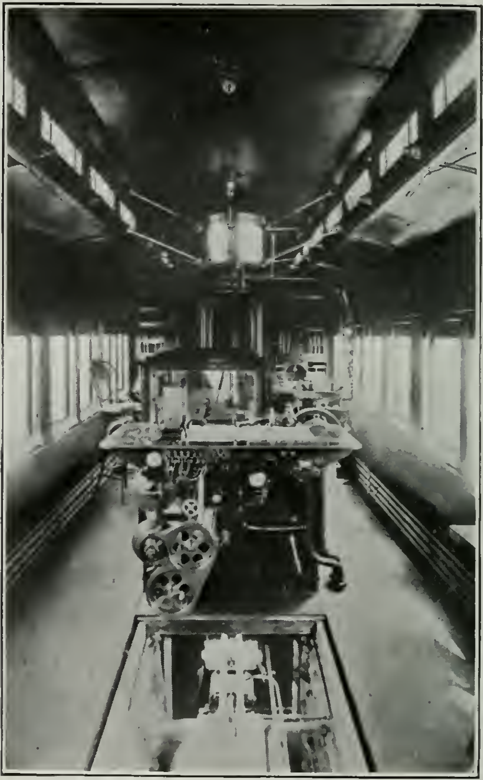
Dynamometer car, exterior, Pennsylvania Railroad.

A number of graphical diagrams were constructed, among which were:

(*a*) Curves showing variation of drawbar pull with speed.

(*b*) Curves showing variation of running speed with the number of cars.

FIG. 9.



Dynamometer car, interior, Pennsylvania Railroad.

(*c*) The alignment and grade of the track.

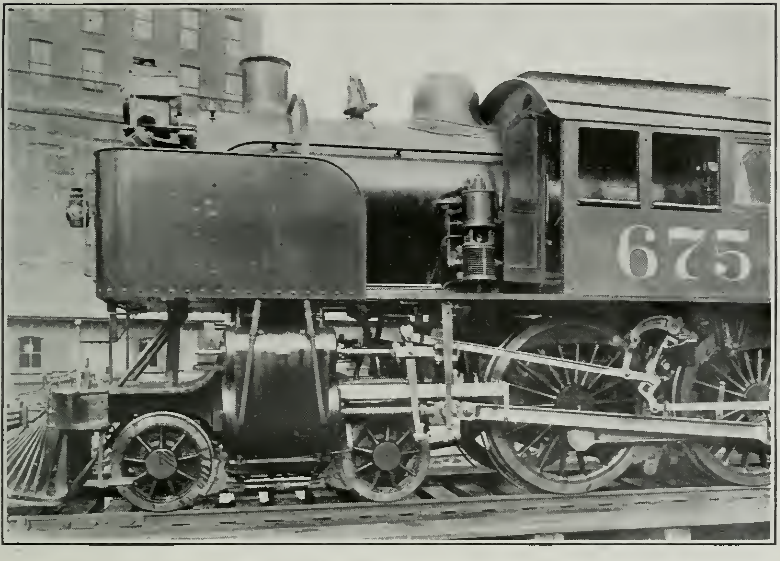
(*d*) The speeds.

(*e*) The time at each station.

(*f*) The direction and velocity of the wind, etc.

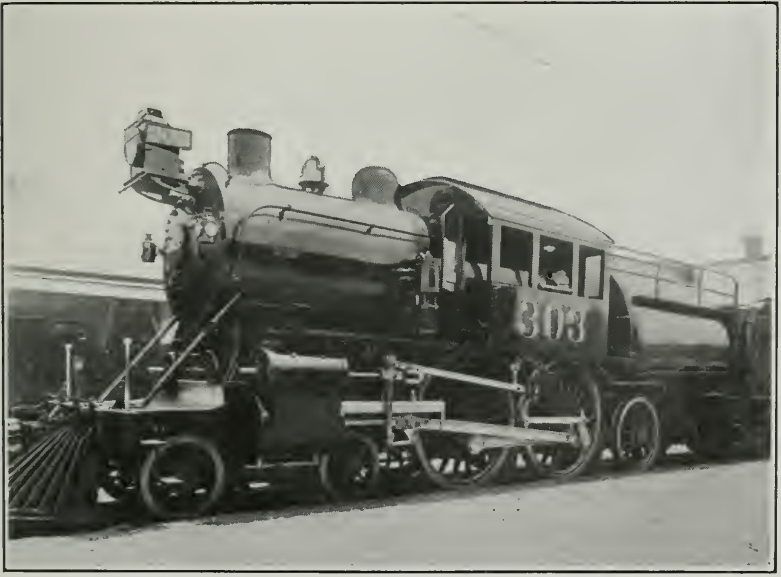
Table I gives a summary of some of the more important results of these tests.

FIG. 10.



Pacific type locomotive, No. 675, Philadelphia & Reading Railroad.

FIG. 11.



Atlantic type locomotive, No. 303, Philadelphia & Reading Railroad.

TABLE I.

SUMMARY OF RESULTS OBTAINED IN THE TESTS MADE ON THE PENNSYLVANIA RAILROAD. FORT WAYNE TO VALPARAISO AND RETURN—210 MILES.

No. of engine	No. of round trips	No. of cars	Average indicated horse-power.	Average dynamometer horse-power	Average speed in miles per hour.	Average drawbar pull in pounds.	Average coal per indicated horse-power. Hour. Lbs.	Average coal per dynamometer horse-power. Hour. Lbs.	Average water per indicated horse-power. Hour. Lbs.	Average water per dynamometer horse-power. Hour. Lbs.	Degrees of superheat above boiler steam. (Fahrenheit)
5075	7	9	1645.5	1000.9	64.46	5454	5.316	8.742	27.17	44.66	0
		10	1662.2	995.0	68.00	5442	4.472	7.471	27.39	45.75	0
		11	1511.3	1075.0	63.55	6254	4.708	6.616	29.49	41.46	0
		12	1539.9	1108.1	60.33	6767	4.564	6.343	28.95	40.26	0
		13	1665.1	1150.1	62.43	6830	4.608	6.673	27.66	40.05	0
		14	1782.3	1200.2	58.80	7535	4.346	6.454	26.15	38.83	0
		15	1686.6	1205.5	56.70	7863	5.911	7.011	27.09	37.90	0
7514	6	9	1843.6	1133.8	69.09	5933	3.008	4.892	20.17	32,80	235.3
		10	1882.9	1112.8	69.61	5875	2.925	4.950	18.84	31.88	
		11	1768.3	1165.3	65.60	6532	2.795	4.242	20.00	30.35	199.3
		12	1745.7	1171.4	66.98	6446	2.992	4.459	19.53	29.11	209.8
		13	1717.0	1162.4	62.51	6816	2.917	4.308	20.03	29.59	214.7
		15	1953.1	1334.0	62.78	7853	2.844	4.164	19.45	28.48	220.6
9996	7	9	1459.1	846.3	60.42	5178	3.747	6.462	26.63	45.92	0
		10	1307.7	780.7	57.78	4983	3.687	6.343	28.80	48.24	0
		11	1401.4	838.0	57.06	5420	3.949	6.605	28.12	47.02	0
		12	1548.5	992.6	57.43	6366	4.310	6.724	27.97	43.64	0
		13	1683.3	1100.9	57.59	7063	4.822	7.373	26.08	39.88	0
		14	1694.9	1139.0	56.80	7440	4.858	7.237	26.84	39.94	0
		15	1723.9	1179.2	55.54	7884	4.849	7.091	26.77	39.00	0
9999	6	9	1419.8	795.0	61.23	4737	3.539	6.321	30.06	53.69	0
		10	1447.3	850.3	60.33	5201	3.736	6.361	29.33	49.92	0
		11	1571.5	955.2	60.18	5855	4.373	7.194	27.77	45.68	0
		12	1687.8	1021.6	50.59	6263	4.006	6.618	28.46	47.02	0
		13	1785.0	1099.7	54.63	7379	3.662	5.943	26.51	43.03	0
		15	1697.2	1165.1	54.46	7907	4.373	6.378	27.63	40.25	0

A SERIES OF TESTS MADE FOR THE PHILADELPHIA AND READING RAILROAD BY THE BALDWIN LOCOMOTIVE WORKS IN 1911.

The main object was to determine the hauling capacity and the economy of four-passenger locomotives, viz.:

(1) No. 675; Three-cylinder 19 inch by 24 inch (74-inch drivers) Ten-Wheel type (4–6–0) locomotive, using steam of a low degree of superheat, and hand fired:

Total weight of engine and tender........................178 tons

(2) No. 300; Three-cylinder 19 inch by 24 inch (80-inch drivers) Atlantic type (4–4–2) locomotive, using steam of a low degree of superheat, and hand fired:

Total weight of locomotive and tender.................... 172 tons

(3) No. 301; Two-cylinder 22 inch by 26 inch (80-inch drivers) Atlantic type (4–4–2) locomotive, using steam of a low degree of superheat, and hand fired:

Total weight of locomotive and tender.................... 170 tons

(4) No. 302; Two-cylinder 22 inch by 26 inch (80-inch drivers) Atlantic type (4–4–2) locomotive, using saturated steam, and hand fired:

Total weight of locomotive and tender.................... 170 tons

Fig. 10 shows the first of these locomotives. Fig. 11 shows No. 303 of the same type as the other three.

All the runs were made, in regular service, from Philadelphia to Jersey City, express, and return local, the distance each way being about 90 miles.

The average number of cars hauled was eight, the total weight of train in tons being: For No. 300—633.8; for No. 301—628.7; for No. 302—629.9; and for No. 675—617.

The coal was weighed and analyzed.

The water was measured by means of four water glasses, one at each corner of the tank.

The speed was obtained from the records of the dynamometer car belonging to the Pennsylvania Railroad, numbered 495,591.

Indicator cards were taken from all the cylinders at intervals of three minutes or less.

The drawbar pull was determined from the records of the dynamometer car.

Besides the above, all the other observations necessary for a complete test were taken, as pressures, temperatures, position of reverse lever, opening of throttle, calorimeter readings, draft pressures, etc.

The arrangement of the work was such as to lead to the determination, among others, of the following quantities:

(1) The coal consumed.
(2) The water evaporated.
(3) The indicated horse-power and the tractive power of the engine.
(4) The dynamometer horse-power and the drawbar pull.
(5) The running speed.
(6) The temperature and the pressure of the steam.
(7) The priming.
(8) The temperature of the hot gases.
(9) The draft in the smoke-box.
(10) The amount of smoke.

Graphical diagrams were constructed, on which were recorded:

(*a*) The make-up of the train.
(*b*) The location where cards were taken.
(*c*) The throttle opening.
(*d*) The cut-off.
(*e*) The boiler and steam-chest pressures.
(*f*) The superheat, based on steam-chest pressure.
(*g*) The superheat, based on boiler pressure.
(*h*) The draft, and the temperature in the smoke-box.
(*k*) The speed.
(*l*) The tractive force of the engine.
(*m*) The drawbar pull.
(*n*) The profile of the road.

Table II gives some of the more important results of these tests.

TABLE II.

SUMMARY OF SOME OF THE RESULTS OF THE TESTS MADE ON THE PHILADELPHIA AND READING RAILROAD BY THE BALDWIN LOCOMOTIVE WORKS. PHILADELPHIA TO NEW YORK—90 MILES.

No. of engine	No. of trips	No of cars	Average indicated horse-power.	Average dynamometer horse-power.	Average speed in miles per hour.	Average drawbar pull in pounds.	Average coal per indicated horse-power. Hour. Lbs.	Average coal per dynamometer horse-power. Hour. Lbs.	Average water per indicated horse-power. Hour. Lbs.	Average water per dynamometer horse-power. Hour. Lbs.	Degrees of superheat above boiler steam. (Fahrenheit)
675	3	8	1360	857.0	57.40	5414	4.50	7.13	28.0	44.36	51
		8	1293	816.7	54.93	5513	4.48	7.10	27.9	44.22	0
		8	1261	820.4	54.91	5536	4.36	6.57	27.8	42.58	60
300	5	8	1343	870.0	56.00	5730	4.70	7.28	24.2	37.48	65
		8	1162	850.0	56.70	5550	5.52	7.54	28.8	39.60	65
		8	1377	943.3	56.81	6120	4.52	6.66	25.0	36.46	61
		8	1312	909.6	55.10	6180	5.22	7.36	24.6	34.74	71
		8	1386	945.5	56.60	6120	5.42	7.96	23.7	34.79	66
301	3	8	1319	889.4	57.14	5700	4.52	6.71	24.3	36.54	41
		8	1211	869.4	54.30	5910	4.98	6.98	27.7	38.89	51
		8	1155	870.0	53.38	5970	5.35	7.10	29.1	40.61	46
302	3	8	1414	857.6	56.20	5640	4.51	7.21	24.8	39.85	0
		8	1264	868.8	53.74	6000	4.75	6.91	26.0	38.99	0
		8	1133	892.5	57.32	5760	4.81	6.06	33.4	42.12	0

The figures in Tables I and II are published by kind permission of Mr. S. M. Vauclain, Vice-President of The Baldwin Locomotive Works, Philadelphia, and of Mr. A. W. Gibbs, Chief Mechanical Engineer of the Pennsylvania Railroad.

NATURAL GAS, WITH INCIDENTAL REFERENCE TO OTHER BITUMENS.*

BY

I. N. KNAPP, M.E.,

Consulting Engineer.

This storing process could not, of course, go on indefinitely, since the new reservoir would require additional pressure to force the gas further and further back in the rock, and the conclusion was reached that in time the rock pressure of the well would show a large increase, and that the gas, being thus stored up in natural reservoirs, would be available for future consumption. This conclusion was subsequently verified.

West of Chanute, Kansas, I completed[50] a gas well in February, 1903, that gave about four million cubic feet open flow capacity and 315 pounds closed pressure, and gave dry, clean gas. I left the well closed in. Soon after a boom company drilled a well one-quarter of a mile north and got some oil above the gas. This well was allowed to stay open for weeks, wasting the gas, presumably to make an oil showing to sell stock with.

In December, 1903, my well showed 275 pounds closed pressure, and about one million cubic feet open flow, and some salt water. No other wells were then within a mile or more of these two.

These examples show the migratory and elusive character of gas in porous rocks.

At Chanute I used, for a few months, the natural gas under rock pressure from two wells for blowing or pumping oil wells and pumping from field tanks. I then put in gas engine driven air compressors to supply compressed air for the same operations.

The rock pressure of the two wells had fallen from 305 to 125 pounds, and the gas then showed wet. I hitched these two wells on my air line as air receivers or compensators and restored the rock pressure to 290 pounds of air and drove back the salt water. In this way I could, for a while, use compressed air to many times the capacity of my compressors; also, I could shut down my compressors without affecting my field operations. This shows what, I believe, was a new use for a reservoir rock.

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* Continued from page 498.

[50] Drilled about the centre of N. W. ¼ Sec. 24-27-17.

SECTION VI.

NATURAL GAS SANDS.

Any porous or reservoir rock in a horizon where paying pools of oil or gas occur is called by the drillers a "sand," whether it be a sand or a limestone rock. When this "sand" is drilled into and oil or gas, or both, are found in paying quantity, it is called a "paying sand," and if not found in paying quantity the well is said to be a "dry hole" or a "duster," and the sand is said to be "dry," although it may be heavily charged with salt water.

The popular idea is that both oil and gas are found in one large cavern [51] or in several connected together in a sort of underground stream.

This is a great mistake, for crevices in oil and gas rocks, especially where they lie deep below the surface, are of rare occurrence.

The drillers oil and gas sands are rocks that are pierced with millions upon millions of minute connected pores, which may readily be observed with a good microscope magnifying to from twenty to thirty diameters. When such rocks are saturated with oil or filled with gas under pressure they become the paying pools and fields of oil and gas. Geologically speaking, the oil and gas rocks are identical and have a common origin. Pools of natural gas are much more generally distributed and occupy a larger area than the oil pools.

Oil always has more or less gas associated with it, in the same porous rock in all classes of accumulations; but, on the contrary, gas occurs in fields and pools entirely separate and free from oil and in porous strata by itself.

When an oil well is shot, pieces of saturated rock are some-

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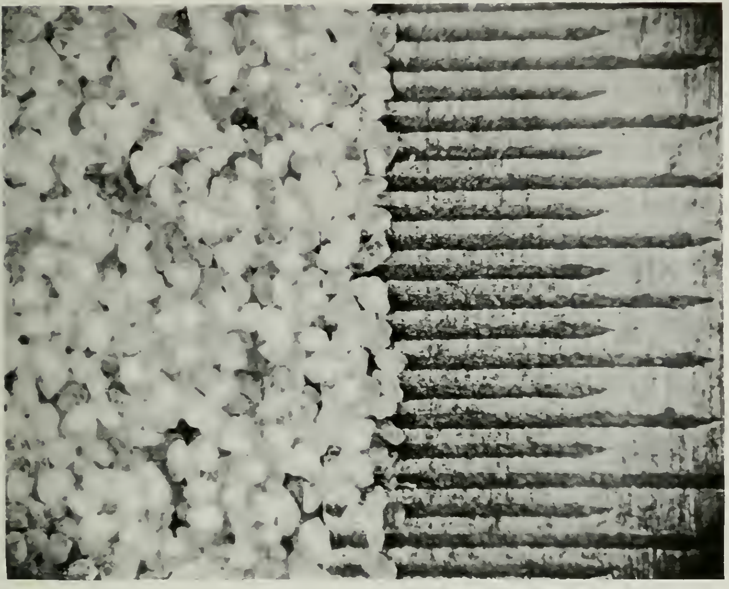
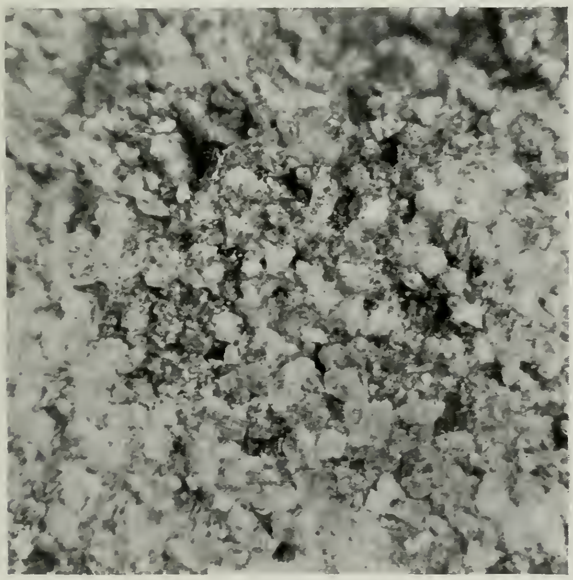
[51] West Virginia Geological Survey, vol. i (a), p. 45. Eleventh Annual Report U. S. Geological Survey, part i, p. 657. Penna. Second Geological Survey, vol. iii, p. 247.

FIG. 9.



Sand held on No. 80 sieve but passed a No. 40 sieve. The dimensions shown are $\frac{1}{100}$ of an inch, Brown & Sharp rule.

FIG. 10.

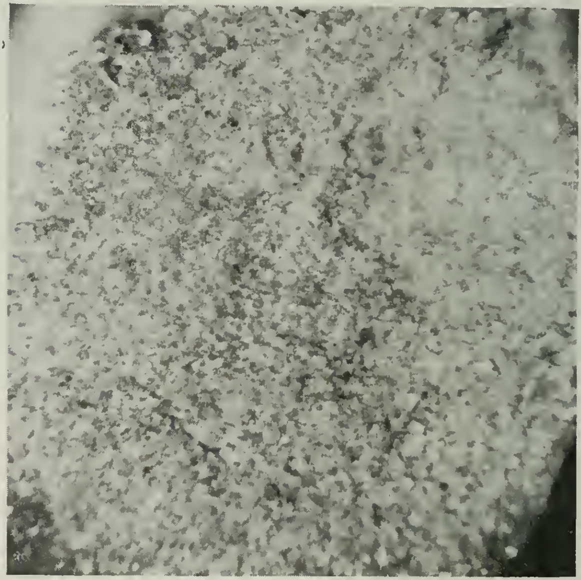


Gas sand from a 34,000,000-foot well on the B. Johnson farm, south of Independence, Kansas. A coarse, open sand; little cementing material.

times thrown out. An immediate examination of such pieces often shows a bubbling and hissing caused by the escape of oil and gas from the pores.

Fig. 9 is a microphotograph,[52] on a scale of twenty to twenty-five diameters, of a loose sand held on a No. 80 sieve but passed by a No. 40, and the divisions shown are spaced one one-hundredth of an inch. This has no cementing material, and its pore space [53] is probably 38 to 40 per cent.

FIG. 11.



Chanute, Kansas, gas sand from a well. Fine, close sand with much cementing material. A 3,000,000-foot well.

Also, on the same scale, have been made a number of microphotographs of specimens of oil and gas rocks, or sandstones and limestones, commonly called "producing sand."

Fig. 10—Specimen of sand from B. Johnson well, south of Independence, Kansas. It came from a well giving an initial open flow capacity of 34,000,000 cubic feet per 24 hours. It is coarse grained, with little cementing material and a rich gas sand.

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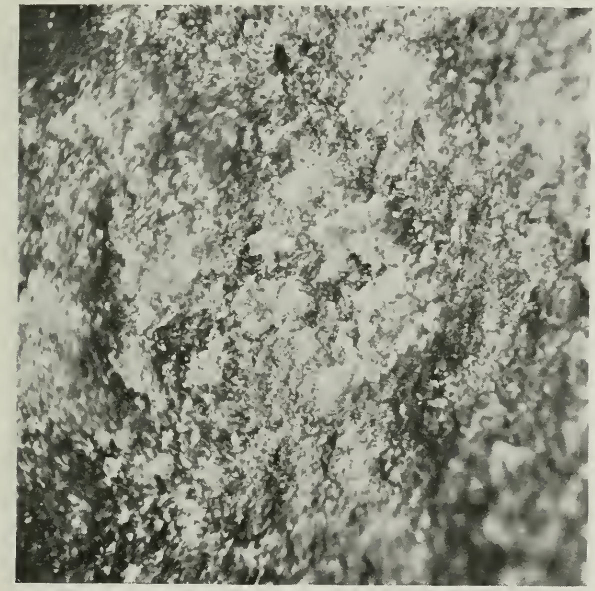
[52] Microphotographs made under direction of Mr. C. O. Bond.

[53] U. S. Geol. Survey, 19th Annual Report, table p. 91.

Fig. 11—Specimen of sand from Chanute, Kansas. It is from a well that gave 3,000,000 cubic feet initial open flow capacity, and is a fine-grained rock with average amount of cementing material.

Fig. 12—Specimen of the Trenton limestone from northwestern Ohio. It was given me as a fair specimen of the top of the producing sand.

FIG. 12.



Top of Trenton rock, N. W. Ohio gas field. Coarse open limestone rock.

Fig. 13—Specimen of the Onondague limestone from the Kent gas field, Ontario, Canada. This is a fair gas-producing sand; the wells measure from 500,000 to 6,500,000 initial open flow capacity, and hold up good.

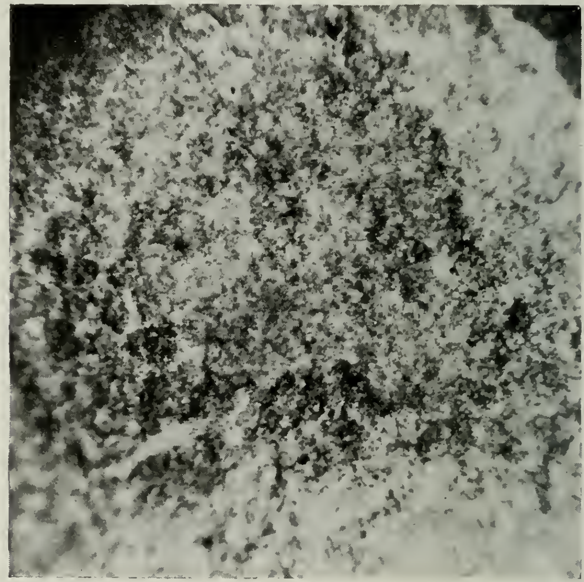
Fig. 14—Specimen of gas sand from a well in the Caddo, Louisiana, field that measured 82,000,000 cubic feet open flow capacity per 24 hours. This is a very fine grained sand. A close examination under the microscope shows it is high in pore space, probably one-third. It is a very friable and soft sandstone.

Fig. 15—Specimen of gas sand from Terrebonne Parish,

Louisiana. This is a very soft stratified sandstone from a well that blew out and was lost, but the specimen has all the characteristics of a true gas sand. This is believed to be from the Quarternary system, so, geologically speaking, is of very recent origin.

Fig. 16—Specimen of salt from Belle Isle, Louisiana. (Specimen taken by Mr. A. C. Veatch and photographed by U. S. Geological Survey.) This is extremely interesting, as it shows globules of oil and gas imprisoned in the salt, and the connected porous condition necessary for the production of oil and gas does not occur.

FIG. 13.



Onondague limestone from the Kent gas field, Ontario, Canada; fine-grained rock

Sandstones [54] have a porosity of 10 to 38 per cent., depending on the amount of cementing [55] material deposited from solution in the interstices of the original sand through the agency of ground waters.

Limestones have a greater range of porosity than sand-

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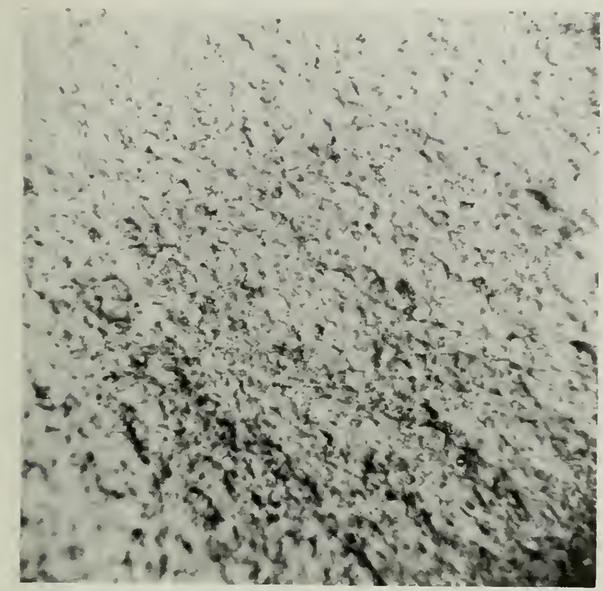
[54] U. S. Geol. Survey, 19th Annual Report, table p. 91.

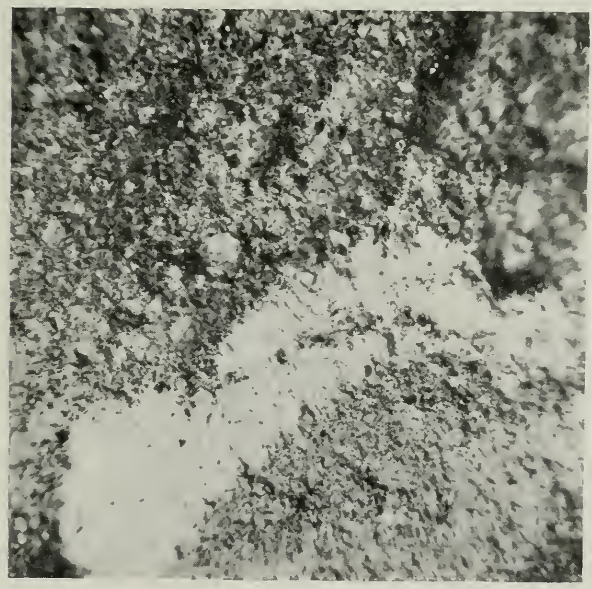
[55] U. S. Geol. Survey, Water-Supply and Irrig., paper No. 67, p. 17.

FIG. 14.



Caddo, La., gas sand; from an 82,000,000-foot well. Very fine grains, lightly cemented. Must be one-third pore space.

FIG. 15.

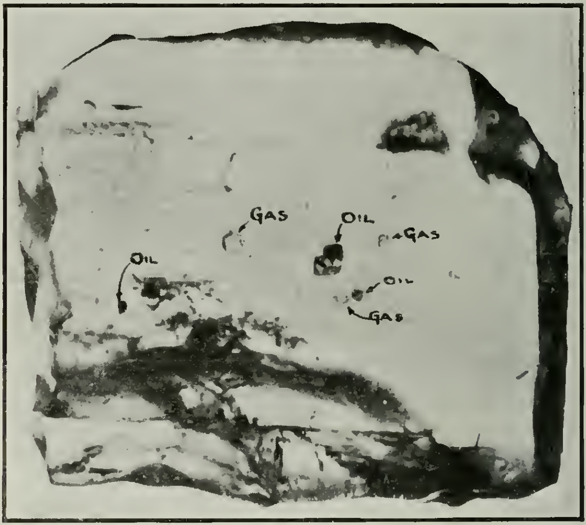


Terrebonne Parish, La., gas sand. This sand is from Quarternary material, and so is, geologically speaking, way up on top above any productive gas sand. Material soft and no well yet saved in it.

stones. Some have a natural porosity due to their fossiliferous character. Some have been changed chemically, causing recrystallization in smaller forms, reducing the space occupied, and thus causing porosity. Some porosity may have been caused or enlarged by dissolving action of circulating ground waters both in limestones and sandstones.

At Belle Isle, Louisiana, I drilled in one very porous limestone stratum that may have been one-third pore space and was full of sulphur water, but occupied relatively the same position to the salt and sulphur as the productive oil rock at Spindle Top.

Fig. 16.



Belle Isle, La., salt impregnated with oil and gas. Specimen taken by Mr. A. C. Veatch and photographed by U. S. Geological Survey.

According to Carll,[56] experiments in a crude way show that the porosity of the oil- and gas-bearing sandstones of Pennsylvania is from one-tenth to one-fifteenth of their bulk, and might even hold one-eighth under normal conditions. White [57] puts the proportion of pore space in a fairly good producing oil- or gas-bearing sandstone in West Virginia at from one-fifth to one-tenth. The limestones are more variable in porosity, but it is fair to assume one-tenth as the average.

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[56] J. F. Carll in Pa. Second Geol. Survey, vol. iii, pp. 251-253.

[57] I. C. White, in W. Va. Geol. Survey, vol. i (a), p. 45.

Assuming a pay streak ten feet thick and an available porosity of one-tenth, we would have one foot in depth of oil, or 43,560 cubic feet, or about 7,500 barrels per acre. This is probably better than the average per acre yield in any one horizon of the Paleozoic rocks of the United States. Three thousand barrels per acre was fully as much as the yield in Kansas, where I operated.

Rocks of the same porosity filled with gas at 30 atmospheres (450 pounds) would hold 1,300,000 cubic feet per acre; or a gas well flowing at the rate of 1,300,000 cubic feet per 24 hours from a rock pressure of 30 atmospheres would relieve as much pore space as a well flowing 7,500 barrels of oil in the same time. By pumping, the gas may be exhausted down to or below atmospheric pressure and thus at least 95 per cent. of the gas produced. It is doubtful if over 75 per cent. of the oil in a sand is obtained in any case.

The total production of natural gas in the United States is now around 500,000 millions of cubic feet per year. If this gas had originally the assumed average rock pressure of 30 atmospheres, it would require a pore space of 16,666 millions of cubic feet to contain it. The same space filled with oil (1 barrel = 42 gal. = 5.6146 cubic feet) would hold 2,968 millions of barrels, or more than the total production of oil in the United States from the beginning to the present time.

Using our estimated yield of 1,300,000 cubic feet of gas per acre from the assumed 10 feet of 10 per cent. pay sand, it would require about 600 square miles of such a sand to supply a year's consumption of natural gas in the United States.

The figures assumed are tentative and an approximate to the actual.

The original [58] natural-gas field in Indiana occupied an area of 2,850 square miles of almost continuous territory of the Trenton rock. The initial rock pressure in 1886 was 325 pounds to the square inch.

At the end of 1902 this pressure had declined to an average of about 50 pounds, which represents only 15½ per cent. of the original volume.

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[58] Production of Natural Gas 1902, Mineral Resources of the U. S., p. 36.

This field was exhausted at the rate of about 175 square miles per year. Properly conserved for domestic use, not over twenty square miles would have been used per year.

SECTION VII.

DRILLING GAS WELLS.

The art of drilling wells in solid formations with a cable and percussion tools for water, brine, and to prospect for minerals is many hundreds of years old. Formerly it was a very difficult, tedious, and expensive operation to drill a deep well, but now one can be sunk 2,000 to 3,000 feet at a moderate cost and in a comparatively short time. The methods of drilling and tools employed are practically the same in drilling for water, oil, or gas.

It took the city of Charleston, S. C., twelve years (1846 to 1858) to sink an artesian well to a depth of 1,260 feet and at a cost of over $30,000. The flow obtained was thirty gallons per minute.

In the same city, in the early part of 1911, an artesian well was sunk 2,007 feet in 92 working days of ten hours each, at one-third the above cost. The flow obtained was 450 gallons per minute.

The development of the Pennsylvania oil and gas fields gave a great impetus to the art of drilling with cable tools in solid formations.

It took Colonel Drake from May 20th to August 28th, 1859, to get in 36 feet of drive pipe to bed rock, drill 33½ feet (total 69½ feet), and bring in the first oil well.

I have had two men put in a joint (20 feet) of 8¼-inch drive pipe and drill to 70 feet in one tour of twelve hours.

In Colonel Drake's day a man could carry a string of cable tools on his shoulder. Now it is not uncommon to use an auger stem weighing 2,000 to 2,500 pounds and a string of tools weighing between 4,000 and 5,000 pounds.

Soon after the Burning Springs, West Virginia, oil development began, in 1860, the drilling craze spread all over that State. Many wells were drilled, or at least attempts were made to drill them, which nearly always ended by getting the tools fast and the hole plugged, because the operator had not then learned the art of dealing successfully with rocks that crumble, or cave, and fall into the hole when water touches them. The consequence was drilling for oil and gas was confined to those districts in Pennsylvania and West Virginia where the walls of the wells stand firm after the holes are drilled, even though drilled "wet" and full of water from top to bottom.

It took about thirty years to learn how to drill the softer West Virginia rocks with the standard tools. (See page 147, West Virginia Geological Survey, vol. i.)

The development following the drilling of the Lucas well, near Beaumont, Texas, gave a great impetus to the hydraulic rotary method of drilling.

In the hydraulic rotary method of drilling, a 4-inch drill pipe weighs 11¾ pounds per foot, so at 3,000 feet its weight becomes over 17 tons. This method is a rapid one for drilling soft formations, and has a record of making 1,065 feet in thirty-two hours in an oil well at Corsicana, Texas, but it is an extremely unsatisfactory method to use in prospecting for gas, because of the water pressure employed to flush the cuttings from the hole and the necessity of thickening the water with clay to sustain the walls of the well in very soft stuff, and should not be employed, except, of course, where it is not possible to drill with cable tools.

I know that I failed to satisfactorily use the hydraulic rotary method in wells in very soft ground, where I got indications of oil and gas, and do not know whether the oil and gas were present in paying quantities or not. Also, I drilled through rich gas-bearing strata in two wells without the gas showing or giving any indication of its presence, and these wells were accidentally lost by blowing out, and they then both showed for better than 20,000,000-foot wells before they caved in and shut off.

In drilling with the cable tools a casing is set below all water-bearing strata and above the gas sand, and the well bailed dry and the casing proved to be tight. Drilling is continued with only enough water to "mix the mud"—that is, so the cuttings can be made in condition to be bailed from the hole as often as necessary. In solid formations a gas well seldom comes in suddenly. As the sand is approached in drilling, gas will begin to bubble in the hole. When a large well (10,000,000 or better) is expected so it will require to be shut in the casing, it is best at this time to put a valve on and close the well in and subject it to rock pressure. This may be done quickly by connecting in a nearby well or pipe line and thus test the valve and casing and prove they are in good working condition.

On further drilling, as the well develops volume, it will throw the mud out of the hole. Sometimes the expansion of the gas will freeze the mud and stick the tools, but they soon thaw out. Also, the mud on the tools and walls of the well, when conditions happen just right, will roll into balls the size of coarse shot or marbles, and the drillers will say they have a "pebble sand." After the real productive sand is reached and you have a good gasser the well will "drill itself in" and the tools will float and sometimes come up the hole faster than the cable can be pulled out.

In the smaller wells it may prove best to tube and pack them.

Time forbids I should enter into more detail of the drilling art. The supply dealers' catalogues show a wealth of tools and appliances. To successfully drill, care for, and produce from gas wells requires experience, skill and good judgment, and can best be learned by actual experience. It is a skilled trade or art that experience only can teach.

SECTION VIII.

DEVELOPMENT OF THE NATURAL GAS INDUSTRY.

Our historical account shows that early in the last century in the United States drilling wells in search of brine to get that prime necessity of life—common salt—natural gas in quantity was found and put to a limited use. The tools and method of drilling thus evolved were later (1859) employed by Colonel Drake in drilling the first well ever drilled in search of oil.

The successful outcome of this venture gave birth to the petroleum industry, and its development, in turn, incidentally showed Nature's great stores of that perfect fuel, natural gas.

At first the gas associated with the oil from oil wells was regarded as a dangerous nuisance, and carefully led away from the well in pipes and burned to get rid of it.

After a little, however, this casing head gas began to be used for fuel under the boilers in drilling and pumping oil wells and for light and fuel in the immediate vicinity of the wells.

The proportion of gas thus produced that reached actual[59] use was formerly very small. Recently such gases have been liquefied and gasoline and other products profitably produced.

Burning Springs,[59a] West Virginia, now a village of 250 inhabitants, was, in the spring of 1861, a boom town of 6,000, "every part of which was rendered brilliant by mains filled with natural gas."

During the '60's, in wildcatting for oil, wells producing natural gas only were found. Little, if any, attempt was made to utilize this gas, and the production was allowed to waste into the air. From such wells the "dry gas" of commerce is produced and distributed for light, heat, and power.

The Leechburg[60] gas well was drilled in 1871 for oil, but proved a strong gasser with salt water and was allowed to blow for some months. It was bought by Rogers & Burchfield, a separator put in to take out the water, and the gas put in use in their iron works in April, 1873, for heating and puddling iron, and was the first gas to be so used.

The Newton well, on the Nelson farm, 5¼ miles northeast of Titusville, Pa., was finished in May, 1872. It measured 4,000,000 feet open flow and had a closed pressure of 350 pounds. The well was purchased by Mr. Henry Hinkly, who put in a two-inch line to Titusville and delivered gas to that city August 1, 1872.

The two-inch line was too small, and a 3¼-inch was laid, and at the close of the year 250 consumers were using gas for heating and lighting.

Titusville thus had the first natural-gas plant which supplied light and heat in a large and permanent quantity by methods and appliances that are practically the same as those used to-day, and it is looked upon as the beginning of the natural-gas industry that has since assumed such large proportions.

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[59] Technical paper 10, Department of the Interior, Bureau of Mines.

[59a] West Virginia Geol. Survey, 1911, p. 8.

[60] Henry's "Early and Later History of Petroleum," p. 208.

In 1873 there were numerous localities [61] in Venango, Butler, and Armstrong Counties, Pennsylvania, in which natural gas was introduced and successfully used for fuel and light.

In 1875 a 17-mile 6-inch gas line was built from Butler County to Etna, near Pittsburgh, and the gas utilized at the iron mill of Spang, Chalfant & Co. for a number of years with great success.

The Haymaker well,[62] at Murrysville, was drilled in 1877. This wasted gas to the equivalent of 1,000 tons of coal per day for five years.

It was not until 1883 that this great storehouse of potential energy was made useful by Pew & Emmerson, who laid a pipe line to Pittsburgh and supplied consumers. By the close of 1883 several pipe lines were supplying gas for domestic use and to manufacturers of iron, steel, and glass in the Pittsburgh district.

In June, 1884, the celebrated Westinghouse [63] well came in, and this greatly accelerated the natural-gas industry, which rapidly reached enormous proportions in the Pennsylvania fields, and, as this field weakened, lines were extended into West Virginia.

The value of natural gas having now been fully demonstrated to capital, a large amount of money was thus made available for investment in gas territory, gas wells, and pipe lines.

In November, 1884, the first high-pressure gas was found in the Trenton limestone in Ohio, at Findlay. It was put to domestic use the following year.

On January 20, 1886, the Karg well was struck, and from this on the development of that district was rapid.

These large productions of gas and oil from the Trenton [64] (Lower Silurian) limestone were entirely unexpected. It would be hard to say whether the geologist or the producer was most surprised by these results. No one suspected it, or at least no one had prophesied it.

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[61] "Production of Nat. Gas, 1902," by Oliphant.

[62] Mineral Resources U. S., 1885, p. 177.

[63] Am. Inst. Mining Engineers, vol. xiv, p. 668.

[64] Dr. Orton, Geol. Survey of Ohio, 1890, p. 106.

The Kokomo[65] No. 1 well developed an open flow of 2,000,000 feet in October, 1886, and from this dates the development of the Indiana field, which also took place with great rapidity.

With these remarkable and sudden discoveries of such quantities of natural gas that were heretofore unknown the impression became general that the reservoirs of this best of Nature's fuels were inexhaustible.

The climax[66] was reached in 1888, when it is estimated 750,000 millions of cubic feet of natural gas was consumed and wasted in the Pennsylvania and Trenton rock fields.

In 1882, in drilling for oil seven miles northeast of Paola, Kansas, natural gas was developed.

In 1884 a franchise was obtained from that city, which has ever since been supplied with gas from this immediate vicinity.

In 1892 Coffeyville was supplied with natural gas; then Cherryvale and Independence in 1893; Neodesha and Iola in 1894; Humboldt in 1895. Chanute was supplied in 1896 from a well 16 miles west of town by the Prairie Oil and Gas Company.

The coming in of the Lucas well, near Beaumont, Texas, in January, 1901, gave a great boom to wildcatting for oil in the mid-continent (Kansas-Oklahoma) field. Hundreds of companies were formed and an immense amount of wildcat work done, and by the mid-year of 1902 oil and gas enough were shown to attract experienced operators.

The production of oil in the mid-continent field was 81,186 barrels in 1900, and 49,459,739 barrels in 1910.

The production of natural gas was unquestionably proportional, but there are no figures to give it in cubic feet.

During 1905 a large consolidation of gas companies took place in Kansas. Extensive pipe lines were laid in eastern Kansas, extending into the Joplin district, Missouri, and many additional cities supplied with natural gas.

During 1906 gas-pumping stations were completed and gas supplied to Kansas City and St. Joseph, Mo., and other places. Also, Oklahoma developed some large gas wells and some twenty towns and cities were supplied during this year.

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[65] Mineral Resources of U. S., 1886, p. 509.

[66] Mineral Resources of U. S., 1902, Production of Natural Gas, p. 10.

Since 1906 an immense amount of gas has been developed in the mid-continent field, and a population of over 1,000,000 is now served with gas for domestic consumption from it. Additional gas-pumping stations have been put in and pipe lines extended, but no new areas of importance have been added to the field.

Professor Haworth,[67] in a recent report (November, 1911), states that from two to three years, under present conditions, is as long as natural gas may be expected to be delivered to Kansas City, Missouri.

During the year 1905 a new gas area was opened near Caddo Lake, north of Shreveport, La.

In 1907 Shreveport, Texarkana, and a number of smaller places piped for gas.

The Caddo field now supplies natural gas as far north as Little Rock, with branch lines to many towns; also to towns and cities in Texas.

The companies planning to pipe natural gas to St. Louis and New Orleans from the Caddo field have apparently abandoned their projects.

Some gas has been developed in Texas.

A promising field has been found in western Alabama. It is impossible to say what stores of natural gas Nature has hidden away for future use.

It is probable the best fields contiguous to populous or manufacturing centres are known and have been exhausted or seriously depleted.

That there will be great fields developed in the United States in the future I do not doubt, judging from the past, but it is dangerous to prophesy of them.

Time will not permit me to speak of pipe lines, compressing stations, appliances for distribution, combustion, and details of the various uses of natural gas, nor to take up the matter of its possible chemical value.

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[67] See "An 'Expert's' Opinion on Gas," *Oil and Gas Journal,* November 30, 1911.

SECTION IX.

PROPER USE OF NATURAL GAS.

Some years ago (1897) Dr. Edward Orton made investigations for the State of New York on petroleum and natural gas. Dr. Orton was an eminent geologist, a man of many accomplishments, and one of the most honorable and lovable of men. He has since passed away. I cannot do better than to quote his words on the " Proper Use of Natural Gas." Dr. Orton wrote as follows:

" Natural gas is the best fuel known to man. No advance beyond it is possible, but to secure the best results some scientific knowledge is required in regulating its combustion. Since it is the perfect fuel, it admits of application to almost every purpose to which fuel can be turned. The principal exception is in the manufacture of iron from its ores and in other similar metallurgical processes. In the working of iron on rolling mills, forges, and foundries, and in the production of steam for all its multifarious applications, in the direct use of heat, in the manufacture of glass and cement, in the burning of pottery, tile, and brick, it is, as before said, the perfect fuel. It effects important economies and greatly improves the quality of production at the same time. But superlatives in describing its advantages and value ought to be reserved for its use as a household fuel. It is here that it does the greatest good to the greatest number. It lightens and simplifies the labors of housekeeping to a surprising extent.

" The truth is that natural gas ought to be exclusively confined to domestic use. It is too good for any other line of service, too fine a product for the coarse applications already named. It is a profanation of the good gifts of Nature to use gas in burning bricks and tile, in calcining limestones, in generating steam, in the manufacture of glass or cement. There is not enough of it anywhere for manufacturing purposes. The most prolific districts for its supply thus far known in the world have been exhausted in a single decade.

" The amount of gas required in manufacturing necessitates the speedy decline and failure of every gas field, even the greatest.

" Iron working demands by far the most lavish and unwarrantable use of gas of all manufacturing industries. A rolling mill will range from 1,000,000 to 5,000,000 feet a day. How far will a million feet go in the support of household use? A house of 12 rooms, using gas in cooking, range, laundry, furnace, and in six grates, uses on an average for the year about 40,000 cubic feet a month, or 1,333 feet a day. One million feet would supply 750 such establishments, or what the smallest rolling mill would use in a day would serve such a home for more than two years. But, instead of using 1,333 feet a day, the average residence will find all its necessities met by less than one-half the amount named. Five hundred feet will make an ample daily supply for the majority of city or village homes. For such use the amount consumed in the smallest rolling mill in a day will serve 2,000 ordinary residences for the same length of time, or would serve one such dwelling for 2,000 days. A ten-pot window-glass factory uses what would supply 1,200 dwellings for an equal length of time.

"The sacrifice of human comfort and well-being to business greed finds a striking illustration here, and cannot be too emphatically condemned. The application of natural gas to manufacturing uses necessarily involves such a sacrifice.

"*Whoever has occupied for a year a dwelling adequately supplied with natural gas will recognize so many and so great additions that it makes to the comfort of life that he will not insist on a very close balance of expenditures and credits in dealing with this subject.*

"When applied to manufactures it is doubtful whether natural gas works in the interests of the general good. It is true that the cost of manufacture is cheapened and the quality of the production is likely to be improved by its introduction. But the fortunate manufacturer who can avail himself of it at once begins to undersell his competitors who are working under the old conditions, because his fuel, which is often the most costly element in his business, costs him nothing. In this way the most prudent manufacturer carrying on his business in the old way may find himself forced to the wall. Competition for him is simply impossible till the storm is past. Meanwhile the manufacturer who uses natural gas finds his business greatly improved in volume for the time being, because of the discouragement and failure of his natural competitors.

"Such a state of things is not good for any community.

It is much worse when the towns that find gas within their reach invite in manufacturers by municipal grants and the like. Factories come to be established, far from all supplies of essential materials with the one exception of fuel. As soon as fuel fails, the factory is bound to disappear. In many such cases the last state of the town is worse than the first.

"One of the evil results of the use of natural gas in manufactures is the development of the speculative fever called a 'boom' in the towns that find gas at hand. Real estate feels the effect soonest. Inflated values derange legitimate prices, and the reactions that are inevitable are always hurtful.

"The proper use of natural gas—*i.e.*, household use—is the only one that can bring adequate return to the company undertaking to supply it. It is a source of satisfaction to find that the true use pays best.

"*The price of gas ought to be increased in every community that is now using it. There is no good reason why it should be sold at any less price than the fuel which it displaces, or, in other words, why the better article should be sold for less than the inferior.* In computing the cost of the displaced fuel, account should always be taken of the various items involved, such as its storage and preparation, the cost of lighting fires, and the expenses of removing ashes and cinders, none of which enter into the use of gaseous fuel. It may be urged that an increased price for gas would result in extravagant profit for the gas companies. It cannot be denied that there is a possibility of such a result, but, as a matter of fact, there are very few cases in the country in which companies have got back their original investment or see any good chance of getting it back. They are generally obliged to content themselves with generous dividends while the gas is in full flow." (See *Bulletin of the N. Y. State Museum,* vol. 6, No. 30, November, 1899, p. 483.)

SECTION X.

SUMMARY.

For ages the human race has known of natural gas through its surface indications, but the great storehouses of this best of Nature's fuels were unknown and unsuspected until about two generations ago, when by accident the drill of the brine- and oil-producer revealed their presence; and of the vast quantities of gas thus unlocked, the door was at first left wide open for its wasteful escape.

Only forty years have passed since there was effort made to control and utilize this valuable fuel, and it has been too often regarded as a by-product of the oil fields of no special value.

We have learned that porous rocks under proper conditions act as reservoirs or storehouses for oil and gas. When by force we break into them with the drill we find the invisible and practically inodorous gaseous contents under great pressure, and so peculiarly elusive and migratory. If the drill hole be not well guarded it will flee to other places, and, if left open to the air, will escape and be lost.

It is largely because of these characteristics—invisibility and self-escape—that the amount lost is not appreciated. This mobile or migratory condition of oil and gas is reflected in legal decisions.

The Supreme Court[68] of Oklahoma, in a recent decision, "held that oil and gas cannot be sold in the ground, but simply the right to use what comes to the surface. Coal and other minerals go with the ground, as they are part of it, but oil and gas, while of the earth, are not earth, and while oil land can be leased or sold and the oil itself sold after it comes to the surface, it cannot be transformed until after it is out of the ground."

The same rule applies to gas.

If oil and gas were of such a nature they would remain in place like coal we would not have such hard problems to solve in the production of oil, and particularly that of natural gas.

After they are once discovered in paying quantity it is impracticable, under present conditions, to hold them in the ground for a rise in value or for future use.

The boomer, the promoter of fake oil and gas companies, the tales of coal-oil Johnnies, the space-writers for the magazines have the general public very much misinformed as to the actual conditions surrounding the production and marketing of natural gas.

But the statements of those who are in such positions that they ought to know the fundamental facts of the natural-gas business unquestionably do the most harm. Let me quote a few gems of the kind, false though they be; they occur where only the real article is expected to appear.

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[68] See *Oil and Gas Journal,* Nov. 30, 1911, p. 4.

The president of [69] a gas association said, in an address in 1906, of natural gas as follows:

"I believe by its judicious application and husbanding we will have *an everlasting supply* of this greatest of all fuels."

The director [70] of a State geological survey said before a gas association in 1910:

"We are trying to keep our gas at home. We need it. It is true, we have been wasting it about as fast as we could, but at the same time we don't want you all to take any of it away. What we do want is for you to locate factories here that will utilize our fuel. *We have plenty and to spare.* If the gas fields are ever exhausted, we have a few billion tons of coal to fall back on."

The most casual perusal of the publications of the United States Geological Survey would show that an "everlasting supply" is not to be expected, and that no field has "plenty and to spare." In contrast to these statements I quote from the Preface of the Geological Survey of Ohio, 1890, as follows:

"The natural-gas interests of the State have demanded and received in this report a measure of attention that is out of proportion to their intrinsic value. These interests are in marked contrast with the oil interests of the new fields in this respect, *viz.*, that, while the latter are almost exclusively in the hands of those whose knowledge has been derived from a varied and costly experience in the business, the former have been in many instances turned over to persons who have never seen a gas field aside from the particular one of which they are called upon to take charge. It is not surprising, under such circumstances, that crude and erroneous views in regard to the nature of the gas supply should find place among these companies and municipal boards, nor that a wasteful and extravagant policy in the use of the gas should be established or allowed by them. To convince such officials that gas is not being generated in the underlying rocks as fast as their wells are able to withdraw it—that is, strictly stored power—and that every foot taken from the reservoir leaves the amount remaining there so much the less, has been a difficult, and in some respects a thankless, task. Nature has, however, become the teacher of all these communities that have broken into her storehouses of force, and falling pressure and supply-pipes half filled have come even more speedily than was expected to convince all who are able to learn that high-pressure gas fields are always exhausted by use, and that, in fact, they begin to die the moment they begin to live."

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[69] Proc. Nat. Gas Assoc. of Am., vol. i, p. 21.

[70] Same, vol. ii, p. 125.

It is strange how persistent the idea is that oil and gas are being generated in the underlying rocks as fast as wells are able to withdraw them.

I once had the Governor of a great State tell me that oil in a certain field "was being formed right now" in such quantities that the "gushers would never give out," and that scientists had so informed him.

When a great oil gusher is tapped by the drill, even when in a wilderness far from any working pool or field, every effort is made to save this fluid.

The wildcat discoverer, although he may have been "hard up" financially, with no credit at the banks or supply houses the day before, immediately has plenty of credit. The tank builder rushes in tankage; the pipe-line companies rush in miles of pipe lines as the oil is wanted, and for cash as soon as it is in the tank.

When a wildcat well comes in a great gasser away in advance of regular development it is practically a dry hole and loss, so far as the discoverer's immediate finances are concerned, and the driller may wait months before he can get even the first cost of the well back.

Naturally the driller and oil-producer will not be careful of the gas when there is no money in it for them.

The general attitude of municipalities is well shown by the action of the city authorities at Findlay, Ohio.

The Tippecanoe well was drilled in about the close of 1888, some two years after the Findlay field was opened.

The well was located 2½ miles from the court house, on a town lot. To increase the flow the well was torpedoed, and the first 24 hours after the well was shot it made better than 30,000,000 cubic feet.

The well was offered to the gas trustees of the city for $10,000. Instead of purchasing the well when they were short of gas and relieving the situation at once, they purchased an adjoining lot and proceeded to drill a well about sixty feet from the big gasser, expecting to get into the gas at the cost of drilling. Nature had unwittingly provided a tight place in the rock, and they got no gas, and the city's well was a complete failure even after being heavily shot. (See Geological Survey of Ohio, 1890, p. 117.)

Personally I have come across as mean and short-sighted actions as these in other places, much to the loss of the cities and discredit of the local authorities concerned.

Against the improper[71] use and wanton waste of natural gas many have made earnest but unavailing protest, receiving often the curses instead of the thanks of those in whose interests they have labored. To convince the most intelligent and fair-minded members of a community of the justice and wisdom of such views is an easy task, but, unfortunately, people of this kind are in a hopeless minority.

The highest and really the only proper use of natural gas is household use. In this field it meets the supreme test of doing the greatest good to the greatest number. If the world were wise and if genuine good-will controlled the actions of all, every foot of natural gas would be scrupulously saved for this service, but the world is not wise and universal benevolence does not bear sway.

As a practical matter the franchise rates for domestic consumption of natural gas should be much higher. Manufactured gas is sold at $1 per thousand cubic feet in many cities and successfully competes with coal and wood for domestic cooking and lighting.

Why should municipal authorities expect to get a better article for thirty cents or less and bring about conditions that tend to its waste and improper use when a higher price, say fifty cents, would prolong the use of the better article and thus eventually save their citizens a much larger sum than using twenty-five-cent-gas a short time? Why howl about conservation and try to force people to furnish an article at less than a fair cost when such authorities have the means to bring about practical conservation and give their citizens the comforts of natural gas for a long period of time and at a less total cost than to force cheap natural gas for a short time, and then get to manufactured gas at treble the price?

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[71] See Dr. Orton, Bulletin of Geol. Soc. of Am., vol. 10, p. 106.

If the distributing companies get a remunerative price so that they can make natural gas worth a cash price at the well so that there will be a profit to the well owner, in saving gas conservation of natural gas will automatically take place, as well as greater stability to the business.

Metallic Iridium. ANON. (*The Brass World,* viii, ix, 306.)—Iridium is extensively used for the points of gold pens, and is made from the powder obtained in the wet way from platinum ores by heating to a high temperature in a sand crucible and then adding stick phosphorus. The iridium is thus fused as an iridium phosphide. To remove the phosphorus, the phosphide is heated with lime, and metallic iridium is left as a hard white mass, so hard that it cannot be filed or cut and is broken up into small pieces to solder to the points of gold pens. These small pieces are ground to the right size on a copper disc wheel with emery or carborundum. It is stated that an ounce of iridium will make about 5,000 to 10,000 pen points. Iridium, thus prepared, is practically as hard as the ruby, and is the hardening agent in the so-called hard platinum.

A Cartridge Factory for Abyssinia. DAILY CONSULAR REPORT. (*Brass World,* viii, 9, 316.)—As other Powers have prevented the importation of arms and ammunition into Abyssinia, the Abyssinian Government has erected a cartridge factory in the capital, Adis Ababa. The cartridge manufacturing plant has been purchased in Germany and has a capacity of 10,000,000 cartridges per annum. The building is completed and the machinery has been shipped from Germany and will shortly arrive at Adis Ababa. There will be a workshop attached to the factory, in which 15,000 to 20,000 rifles can be repaired each year. The mechanics have been engaged in England and are on their way out to Adis Ababa. Power will be supplied to this factory, and to others in the capital, by a hydroelectric plant supplied by a Manchester firm. This plant is already erected at the power station on the river Akaki, 18 miles from the capital. It consists of two 200 horse-power dynamos, which will transmit 6000 volts to Adis Ababa, to be used both for power and street lighting.

THE PRODUCTION OF AVAILABLE POTASH FROM THE NATURAL SILICITES.[1]

BY

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THE great demand which has recently arisen for an American supply of potash in available form for agriculture has stimulated not only the search for new sources of this material but also experiments on a large and practical scale of operation, in the attempt to develop a method of making the vast supply of potash locked up in feldspars and feldspathic rocks either directly water-soluble or sufficiently soluble in dilute acids to insure a product which shall be useful as a fertilizer. The natural silicites commercially available as sources of potash are chiefly orthoclase and leucite. Both of these minerals are potassium-aluminum silicates. The theoretical formula for orthoclase is written $K_2O.Al_2O_3.6SiO_2$, and for leucite $K_2O.Al_2O_3.4SiO_2$. The principal sodium feldspar albite has the theoretical formula: $Na_2O.Al_2O_3.6SiO_2$. It is well known that these feldspars run into and substitute each other in various proportions, so that the products from different quarries will vary widely in respect to their soda and potash contents. There is an enormous supply of feldspar in the United States, both East and West, which could be made economically possible as a source of potash supply, provided the cost of production can be made low enough to compete with the potash-holding manure salts which are at present so largely imported from Germany. Although it must be admitted that the imported potash salts are richer in potash than any product that can ever be made from American feldspars, it should also be remembered that the crude German manure salts contain large quantities of chloride and sulphates of elements which are not only undesirable in the fertilizer but which may do actual harm under certain conditions. It is this fact which gives encouragement to the attempt to produce from American feldspars a straight potash fertilizer which could be used in exactly the same way that hardwood ashes have been found useful.

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[1] Presented at the Eighth International Congress of Applied Chemistry, New York, 1912, and reprinted by permission of the authors.

Six general methods have been proposed for decomposing the natural silicates, in the effort to obtain water-soluble potash salts.

I. ADAPTATION OF NATURAL AGENCIES.

In the processes of Nature, the slow action of moisture and atmospheric agencies, including the action of carbonic acid gas, is known to have a decomposing or kaolinizing action upon the feldspars. Immense deposits of feldspar and granitic rocks have thus been decomposed, with the formation of large beds of kaolin and clays from which the potash has been leached into the surrounding valley. For this reason, the valleys between feldspathic and granitic hills are usually highly productive of the crops which require large amounts of potash, such as tobacco, potatoes, large fruits, berries, etc. There have been a few processes proposed, which depend principally upon the natural reactions hastened by pressure and other agencies. In 1904 Blackmore (U. S. patent 772,206) proposed the action of carbon dioxide gas under five hundred pounds pressure upon a cream of the ground mineral, repeated intermittently for several hours, in the attempt to produce a yield of carbonate of potash. Ten years earlier the same experimenter (U. S. patent 513,001) had proposed using lime, calcium chloride, and steam pressure in an autoclave to produce chloride. In 1910 Coates (U. S. patent 947,795) proposed the addition of bacteria for the decomposition of feldspar. In 1910 Carpenter (U. S. patent 959,841) proposed to heat the mineral intensely and cool suddenly by plunging in water, in the effort to render the feldspar amorphous, in the hope of making it more available for plant growth. None of the above processes have as yet been shown to possess industrial possibilities.

II. WET PROCESSES OF A CHEMICAL NATURE.

Levi, in 1904 (French patent 344,246 and English patent 13,875), and Piva, in 1905 (French patent 351,338), proposed methods for treating leucite by means of solutions of alkali or alkali earth hydrates, generally under increased pressure. The same general method for treating feldspar was claimed by Swayze in 1907 (U. S. patent 862,676) and by Gibbs in 1909 (U. S. patent 910,662).

Also, Gibbs, in 1904 (U. S. patents 772,612 and 772,657), proposed a process of treatment with hydrofluosilicic acid, and subsequently with sulphuric acid, in order to produce potassium sulphate. In 1907 Cushman was granted U. S. patent 851,922, a public patent which proposed the sludging of finely-ground feldspar with water, the addition of a small amount of hydrofluoric acid, and electrolyzing the mixture in wooden cells provided with wooden diaphragms. Under this process both potassium and aluminum hydrate passed through the cell diaphragm into the cathode compartment. This process, although perfectly practical, has not yet been made commercially possible, owing to the high cost of hydrofluoric acid and the large amount of by-products formed in the process. None of the above processes have as yet been made commercial possibilities.

III. DRY PROCESSES OF A CHEMICAL NATURE, IN WHICH THE POTASH SALTS ARE VOLATILIZED.

In processes of this nature, fluxes, and in some cases fuel, for reducing purposes are ground and mixed with the feldspar, the mixture being subsequently heated until the potash salts are volatilized and collected either in the stack dust or partially collected from the gases by passing them through or over water. Swayze, in 1905 (U. S. patent 789,074), heated ground feldspar with gypsum and carbon, and proposed to collect the volatilized sulphate. Spencer and Eckel, in 1909 (U. S. patent 912,266), made a cement mixed with calcareous and silicious fluxes and green sand, a natural potash-bearing iron silicate, clinkered the mixture in a rotary cement furnace, and obtained a Portland cement, at the same time collecting the potash in the stack dust and the flue gases. In 1911 Eckel (U. S. patent 1,011,172) proposed a somewhat similar method, but heated only high enough to drive off the potash salts and not high enough to clinker the mixture. Again, in 1911, Eckel (U. S. patent 1,011,173) melted a mixture of green sand, limestone, and fuel, tapped off the melted iron and slag, and recovered the potash salts from the flue gases.

Some of the processes under this heading have been tried on a large scale. No great difficulty is recorded in driving off the potash in the furnaces, but obstacles were encountered in the attempt to collect the potash from the gases. As a by-product operation in the manufacture of cements, these processes may yet come to be of some industrial importance.

IV. DRY PROCESSES WHICH PROPOSE TO SEPARATE POTASH AS HYDROXIDE OR CARBONATE.

The old method of Bickell, proposed in 1856 (U. S. patent 16,111), which depended upon heating a mixture of feldspar, lime, and natural phosphate rock or guano to a bright red heat, has not as yet been proved practical or successful. The process of the Soc. Romana Solfati, in 1905 (French patent 352,275), which proposes the roasting of leucite with carbonate, hydrate, or nitrate of soda and lime, and subsequently the passage of steam through the roasted product to produce sodium aluminate and potassium carbonate, is possible from a chemical stand-point, but the high cost of operation has not permitted the process to come into commercial use.

V. DRY PROCESSES PRODUCING THE CHLORIDE.

These processes have been most experimented with upon the mill scale of operation.

In 1900 Rhodin (U. S. patent 641,406) and in 1901 (*J. Soc. Chem. Indus.*, xx, 439) proposed fritting feldspar with lime and salt. According to the published results, this experimenter obtained good yields, although the process has not become a commercial success. In 1907 McKee (U. S. patent 869,011) suggested heating a potash-bearing material containing mica with lime, salt, and carbon in order to obtain a yield of potassium chloride. Cushman, in 1911 (U. S. patent 987,436), proposed mixing feldspar with lime and salts of a mineral acid capable of decomposing the silicate, giving the mixture special treatment previous to heating in a rotary furnace in order to produce the chloride. This method has been tried out on a large mill scale of operation, and the results obtained will be discussed later on in this paper.

VI. DRY PROCESSES PRODUCING SULPHATES.

In 1911 Thompson (U. S. patent 995,105) proposed heating to a bright red heat mixture of feldspar, sodium acid sulphate, and sodium chloride, and subsequently leaching out the potassium sulphate produced. This experimenter claims that potassium chloride is first formed, which is subsequently changed to the sulphate by the action of the acid sulphate. It is stated that this process has recently been tried on a commercial scale of operation. Sodium acid sulphate is a by-product that is reasonably cheap, although a large quantity is not available. The lack of an abundant supply of acid sulphite is perhaps the greatest drawback to the commercializing on a large scale of this process, although it is possible that it may still become of some industrial importance. Hart, in 1911 (U. S. patent 997,671), proposed to fuse feldspar with some barium compound, such as the sulphate, together with carbon, to pulverize the cool melt, and subsequently to digest the product with sulphuric acid and thus produce in solution potash alum and a residue of barium sulphate and silica which is claimed to be useful as a paint pigment. Hart claims that some of the potash is volatilized during fusion. Since the fusion temperature is 1500° C., it is probable that a considerable portion of the potash does volatilize, and it is possible that this difficulty may interfere with the commercial success of the process.

Wadman, in 1907 (U. S. patent 847,856), proposed heating lepidolite with potassium sulphate and leaching the product with sulphuric acid in order to obtain sulphates of lithium and potash.

A chronological list of the patents which have been granted for the treatment of the silicates for the production of available potash is given in Table I.

It would appear that the most promising processes for making potash available from the natural silicates on a commercial scale of operation are those which are conducted in the dry way but without actual fusion of the reacting mixture. Potash salts volatilize readily at the high temperatures necessary for the fusion of the silicates, and the collection of the volatilized potash from the stack gases has not yet been carried out economically. A considerable portion of the potash does not settle in the dust chamber, and if water sprays are used for washing the gases the potash solutions are very dilute and the cost of evaporation becomes prohibitive. Furthermore, water sprays are found to interfere with the draft regulation, even when the use of fans is resorted to. The maintenance of artificial draft is an expensive and difficult matter, and is very likely to interfere with the proper control of the furnace temperatures. For work on the large scale of mill operation, a continuous process must be used, avoiding fusion and with the regulation of temperature to the exact point at which appreciable quantities of potash do not volatilize. The fluxes and reacting substances must be cheap, available in large quantity, and the yields of water-soluble potash salts must be

TABLE I.

PROPOSED EXTRACTION PROCESSES CHRONOLOGICALLY ARRANGED.

	Patentee.	Year.	Process.	Product.
IV	Bickell	1856	Lime, $Ca_3(PO_4)_2$ red heat	Caustic.
I	Blackmore	1894	Lime, powdered $CaCl_2$, H_2O, steam	KCl.
V	Rhodin	1900	Lime, salt, heat under melting	KCl.
II	Levi (leucite)	1904	$Ca(OH)_2$ or NaOH, pressure 16 atmospheres.	K silicate.
II	Gibbs	1904	H_2SiF_6 and H_2SO_4	K_2SO_4.
I	Blackmore	1904	CO_2 500 pounds pressure repeating	K_2CO_3.
II	Piva	1905	(Leucite) KOH, NaOH, steam 25 atmospheres.	K silicate. K aluminate
IV	Soc. Romana Solfati	1905	(Leucite) alkali, carbon, CaO red heat.	K_2CO_3.
III	Swayze	1905	Gypsum and carbon, fuse, volatilize.	K_2SO_4.
VI	Wadman	1907	Lepidolite, K_2SO_4 H_2SO_4	K_2SO_4.
II	Cushman	1907	Water and HFl electrolysis	KOH.
II	Swayze	1907	Heat alone, then KOH solution	K silicate. K aluminate
V	McKee	1907	"Containing mica" with CaO, NaCl, and C.	KCl.
II	Gibbs	1909	$Ca(OH)_2$, steam 150 pounds	KOH.
III	Spencer and Eckel	1909	Green sand cement, mix, volatilize..	K salts.
I	Coates	1910	Bacterial action.	
I	Carpenter	1910	Intense heat, sudden cooling alone	
V	Cushman	1911	CaO, $CaCl_2$, etc., clumps, red heat	KCl.
VI	Thompson	1911	$NaHSO_4$, NaCl, bright red	K_2SO_4.
VI	Hart	1911	Ba compound as $BaSO_4$ and C, fuse, H_2SO_4.	Alum.
III	Eckel	1911	Cement mix but not over 900° C. with green sand volatilize.	K_2O. K_2SO_4.
III	Eckel	1911	Green sand, $CaCO_3$ and C. melt iron volatilize.	K_2SO_4.

high. The process which has seemed to us to give the most promise of successful adaptation to commercial ends is that of Cushman (U. S. patent 987,436), coupled with the method of preparation of the materials before furnacing, proposed and developed by Coggeshall (U. S. patent 987,554).

This process has recently been given extensive trials on a large scale and interesting results have been obtained. The process consists essentially in powdering 100 parts of potash feldspar rock, together with about 20 parts of lime and with or without 10 to 20 parts of rock salt. This powdered mixture is fed to the top of a moving drum about three feet in diameter, in a layer about half an inch deep. As soon as the layer is formed a strong solution of calcium chloride is applied from a series of small tubes. The $CaCl_2$ at once unites with the lime, forming a so-called oxychloride cement, and a large portion of the mixed powder is thereby at once formed into "clumps" or aggregates lying in a bed of surplus powder. As the drum revolves the bed is removed by a scraper to a belt which delivers the mixture to a screen which separates the clumps from the residual powder. The powder is returned by a screw conveyor and elevator to the hopper above the drum again. The clumps are about the size of peas and pass from the screen directly to a rotary kiln similar to those used in burning Portland cement. The kiln is heated by a blast of air and powdered coal in the usual manner.

The clumps pass regularly down through the increasingly heated portions of the rotating kiln and roll out at the end, practically without alteration in size and shape.

A large percentage of the total potash present in the feldspar is converted into potassium chloride during the heat treatment, and very little is volatilized. The dry clumps are of a pale-yellow color outside, due to the iron in the ash of the bituminous coal used, but they are snow-white inside. The clumps are finally ground, producing a pale-yellow material containing as much water-soluble K_2O as hardwood ashes, although the potash is in the form of chloride and the product also contains considerable free lime. Up to the present time no attempt has been made on a large scale to leach out the soluble potash. The ground material is being given field tests as a straight potash fertilizer containing lime.

A RÉSUMÉ OF THE LARGE SCALE EXPERIMENTS.

Potash feldspars were obtained from five different localities. Eleven carloads were used in the trials, amounting to a total of 385 tons. Each carload was ground and analyzed separately. The lowest in potash ran 6 per cent. K_2O and 3 per cent. Na_2O, the highest 11.3 per cent. K_2O and 3.1 per cent. Na_2O; the bulk of the spar 10 per cent. potash and 2 per cent. soda, and the results given in this paper were obtained on the 10 per cent. spar.

The lime was a high calcium quick-lime, running about 90 per cent. CaO and 5.6 per cent. MgO.

The salt was rock salt from New York State and ran about 98 per cent. NaCl.

The calcium chloride was obtained from the Solvay Process Company. It was in the solid form and contained about 75 per cent. $CaCl_2$ and 25 per cent. water.

All of the above materials are available in very large quantities and at low cost. The calcium chloride is a by-product in the form of a moderately strong solution, and but a small proportion is concentrated at the present time, as the chief use is for refrigeration purposes. Vast quantities are now run to waste. The solid form was used in these trials merely for convenience.

Many heats were made with mixtures of varying proportions, but the two mixtures used in the work here described were:

Feldspar	100	Feldspar	100
Lime	20	Lime	20
Salt	10	Salt	20

The feldspar, lime, and salt were separately crushed in gyratory crushers and rolls, and dried in a rotary drier. In continuous work the proper mixture would be made at this point by continuous weighing machines, but as a number of different mixtures were to be tried, each of the three raw materials was ground separately in Huntington mills and put into bins. This preliminary grinding of the feldspar and salt was to about 65 per cent. through a 100-mesh sieve, of the lime about 83 per cent. through the 100-mesh. The weight per cubic foot of each powder of the above fineness was then ascertained, and measuring boxes were built so that the materials could be separately measured out and run together into a large mixing machine. Almost a ton was thus mixed each time. The mixture was then conveyed to a tube-mill and further ground to a fineness of from 97 per cent. to 99.5 per cent. through a 100-mesh sieve, and then conveyed to the bin over the clumper and kiln.

The calcium chloride masses were broken up and thrown on a perforated grid in a large tank holding about 48 tons. Water was run in and the chloride dissolved most readily. The solution was run out when about 42° Beaumé into two large sump tanks, and brought to a constant strength of about 42 per cent. $CaCl_2$. This was then pumped up to an elevated tank and piped from there through a constant-level tank to the dropper tubes of the clumper placed in a row above the drum. This drum is 15.5 feet long and 3 feet in diameter, and is horizontal. There are 15 valved pipes, each one feeding an adjustable pipe holding 38 short dropping tubes of brass 1/16 inch internal diameter and set 5/16 inch apart.

The finely-ground, mixed powder is taken from the bin by a chute, elevator, and screw conveyor and distributed in a long hopper trough over the drum. It is taken from the trough by a roll device and spread evenly on the moving drum at its topmost point. The drum has a surface velocity of about 1.6 inches per second, the layer of powder advancing at this rate.

It was found that by dropping the liquid very rapidly upon the powder the clumps could be made rapidly enough to give a full feed to the short rotary kiln when only one-third of the trough and droppers and drum is used. A clumper drum 5 feet long produces every hour almost two tons of fresh clumps and considerably over a ton and a half of burned product with the kiln used in these trials. The excess of powder passes through a screen and goes to the same elevator which lifts the original material from the bin. The amount of actual $CaCl_2$ in the fresh lime is regulated to about 20 parts to each 100 parts of feldspar in the mixture. The clumps leave the screen in rounded form and flow directly into the kiln.

The reason for the above procedure will now be explained. In the first place, calcium chloride reacts very efficiently under these conditions with the feldspar by replacing the potassium with calcium, thus forming calcium silicate and potassium chloride. Anhydrous calcium chloride is expensive to produce, and it is impracticable to grind it into a mixture on a large scale on account of the rapid absorption of moisture. Even if such a dry mixture could easily be made, its use would present certain disadvantages.

When a reaction between an ore and solid fluxes is produced by heating up to the fusing temperature, the reaction takes place on the surface of the particles alone and only at the points where the ore is in actual contact with the flux particles. Finer grinding will produce a larger surface area and thus a greater number of actual contact points, leading to a larger yield. There is, however, a degree of fineness beyond which it is not wise to go, on account of the cost of extremely fine grinding.

Another factor in the problem is brought out by the following experiments. A batch of ore and the theoretical amount of solid flux were ground together to just pass a 50-mesh sieve. This powder, when subjected to a certain heat treatment, gave a reaction yield of about 35 per cent. of the theoretical. The mixture was then ground to just pass a 100-mesh sieve and given the same heat treatment. A reaction yield was obtained of about 65 per cent. of the theoretical. The mixture was then ground to pass a 200-mesh sieve and again reheated as before. A smaller yield was obtained than when the material just passed the 100-mesh, although the particles were undoubtedly only half the average diameter with about four times the surface area and should therefore have had far more points of contact. Upon weighing equal volumes of the 50-mesh, 100-mesh, and 200-mesh powders, it was found that the latter contained far less material, and it became apparent that the 200-mesh powder consisted for over 54 per cent. of its volume simply of voids. Such finely-ground powders are well known to " surge "—that is, to show the tendency to flow like water through orifices in a manner resembling fountains. Material ground as fine as this is the cause of much trouble at spout slides and conveyors. Each particle of a material of this extreme fineness is undoubtedly surrounded by a film of air, the actual contact with the surface is lessened and friction almost eliminated. When allowed to flow into a bin, such a powder assumes an almost horizontal surface; there is practically no angle of repose. Unquestionably the lessened contact caused the low yields in the finely-ground mixtures. Some of the finer material was briquetted and the subsequent heat yield about 85 per cent. of the theoretical. Briquetting is, however, expensive and usually necessitates the addition of a binding agent foreign to the reaction.

As a result of these investigations, the method was developed for aggregating fine powders by dropping a suitable liquid upon an excess of the powder in such a way as to cause a temporary bond to form, thus practically eliminating the air films or voids around the individual particles and permitting actual surface contact. Under these conditions, with the same ore and flux used in the experiments described above, the same heat treatment yielded within 3 per cent. of the theoretical quantity present. This method of aggregating finely-powdered materials previous to furnacing has already been used in several different ways. For example, in an ore mixture in which the fluxing material is an alkaline carbonate, such as sodium or potassium, which forms crystalline salts containing water of crystallization, if the carbonate is used in the partially anhydrous condition and ground with the ore water alone dropped upon the mix in the manner described formed at once a crystalline carbonate which binds the particles of ore and flux into separate clumps, which are hard enough to withstand screening, while the air films are practically eliminated. Using such a mixture and process as this, a practically theoretical yield was obtained, although the flux was used only in the exact molecular proportion called for by the reaction.

By this clumping process a very intimate contact of reaction of surfaces is readily obtained at a low cost. The quantity of flux necessary to complete the reaction is greatly reduced, the duration and temperature of the heat treatment is lessened, and, working with rotary kilns, dusting and stack losses are almost entirely eliminated. The clumps are beautifully adapted to the feed mechanism of rotary kilns, as they flow easily, do not dust, and take the heat more evenly than fine powders. Now that the temperature conditions in rotary kilns can be accurately controlled, it would seem that many chemical and metallurgical reactions which are now performed by intermittent processes and with low yields could be much more economically carried out in continuous rotary kilns, taking advantage of this new method of forming aggregates previous to furnacing.

In the application of this method to the treatment of feldspathic rock, advantage was taken of the fact that a solution of calcium chloride acts upon dehydrated lime to form the oxychloride, which is a strong cementing compound. It was found that the formation of calcium oxychloride gave a sufficiently strong bond to enable the aggregates to withstand the operation of screening and the burden in the kiln.

The theoretical quantity of calcium chloride flux required depends upon the total quantity of K_2O and Na_2O present in the mix, as it is evident that the soda must also be liberated in proportion to its content. The feldspar ore used ran 10 per cent. K_2O and 2 per cent. Na_2O, which required theoretically 15.5 parts of calcic chloride. In all our trials some slight excess of calcium chloride has been used. The strength of the solution and the method of treatment have been such that about 20 parts of actual calcium chloride are present in the fresh clumps to every 100 parts of feldspar. The 20 parts of lime used are for the purpose of forming the aggregates, and this lime remains practically unchanged in the finished product. The presence of lime in a potash fertilizer will be found advantageous to most soils, and it is generally admitted that lime increases the manurial value of a fertilizer. If the object was to leach out the soluble potash salts from the product, a much smaller amount of lime could be used without interfering with the formation of hard clumps. The salt is added because it has been found to aid the heat reaction, probably mechanically, as will be explained later on. The fresh clumps contain from 16 to 20 per cent. of moisture, which is, of course, evaporated in the upper part of the kiln.

The rotary kiln used in these trials was one of the old bottle shape cement kilns with a total length of slightly over fifty-five feet, the upper twenty feet having a diameter of 4 feet clear inside the firebrick lining, the lower portion widening out to nearly 6 feet inside diameter. The pitch was 7/8 inch per foot, and the most suitable speed was found to be one revolution in about 2½ minutes.

The conditions of the heat treatment are very important. The kiln used was too short to yield the best results, and after the preliminary experiments changes were made which caused the material to take about 1½ hours to pass through the length of the kiln. The temperature of the gases issuing from the upper end of the kiln were read continually with a thermo-couple pyrometer fitted with a 15-foot fire end, and temperatures were also taken from time to time at the firing platform. A furnace wall temperature of about 1370° C. is required for efficient burning of powdered bituminous coal. This is, however, much too high a temperature for potash work in a rotary kiln. This difficulty called for careful experimental investigations and adjustments of the heat treatment before the proper yields could be obtained. If a longer kiln had been available, there is every reason to believe that a more efficient use of the heat could have been obtained. The coal used was a fairly high volatile bituminous coal. It was ground to about 94 per cent. through a 100-mesh sieve and blown into the furnace under an air pressure of about ten pounds per square inch.

During the progress of the clumps down the kiln the following reactions probably take place: At the entrance to the kiln the water begins to evaporate. As the hotter zone is approached, the temperature rises high enough to melt calcium chloride and salt. Whether the calcium chloride is free to melt is not known to us, as the exact composition of the oxychloride compound formed has not yet been determined. The results of our work seem to prove that the reacting chlorine is more readily evolved from the oxychloride compound than it is from calcium chloride alone. The melting of the salt, however, continues the bond of the reacting particles, causing them to thoroughly "wet" each other, and from this point on the attack on the silicate proceeds rapidly. During the heating usually from 1 to 2 per cent. of Na_2O is volatilized.

When operating with no salt present, the yield of soluble potassium chloride was 47.5 per cent. of that originally present in the feldspar. On adding to the mixture 10 parts of salt to each 100 of spar, a test heat yielded 64 per cent., but of this 9 per cent. was lost by volatilization, giving a yield of 55 per cent. net in the final product. On adding 20 parts of salt to the mixture the yield grows to 69.2 per cent. with no volatilization and to 75 per cent. under heat conditions which caused a volatilization of 7 per cent., leaving a net yield of 68 per cent. of that originally present. In the case of clumps made from a mixture of 100 parts of feldspar containing 10 per cent. K_2O and 2 per cent. Na_2O, 20 parts of lime, 20 parts of salt, and 20 parts of calcium chloride, the theoretical composition if no volatilization loss takes place is shown compared with the actual results obtained in the following table:

	Theory.	Analysis.	
Total K_2O	6.25%	5.8%	
Water-soluble K_2O		4.2%	Equals 6.65% KCl.
Loss of K_2O		.5%	As KCl already formed.
Total Na_2O	7.62%	7.1%	52% made into NaCl.
Water-soluble Na_2O	6.37%	5.1%	Showing 1.79% vaporized as NaCl or 26% of that present.

This particular product contained 11.2 per cent. of free lime, and total lime by analysis 15.5 per cent. There was also in this sample about 5 per cent. of free unchanged calcic chloride. The amount of calcic chloride in the various runs made up to the present time has been reduced gradually to about 1 per cent., and it is felt that in the future better conditions of heat treatment will make complete use of the calcic chloride and at the same time raise the yields of soluble potash. In later runs, in which only 10 parts of salt were present in the mix, the theoretical and actual analysis of the product was as follows:

	Theory.	Analysis.	
Total K_2O	6.66%	5.62%	
Water-soluble K_2O		4.5 %	Equals 7.12% KCl.
Vaporization loss of soluble K_2O		1.04%	As KCl already formed.
K_2O insoluble in water		1.12%	
Total Na_2O	4.15%		
Water-soluble Na_2O		3.7 %	Showing 0.45% vaporized as NaCl or 11% of that present.

This product contained 12.25 per cent. of free lime, the total potash rendered soluble was 5.54 per cent. of the product or 83.2 per cent. of the total quantity present, but as 15.6 per cent. had been volatilized the net yield in the product amounted to 57.6 per cent.

The material which was later made continuously according to the process described above carries 4.5 per cent. of water-soluble K_2O in the form of 7.12 per cent. potassium chloride, and in addition to this material carries only 1.12 per cent. K_2O insoluble in water. It is well known that a 2 per cent. citric acid solution will extract, when used according to the Wagner method, somewhat more K_2O than can be made directly water-soluble. This fact is of considerable interest when the product is to be used directly as a potash fertilizer.

CONCLUSION.

It is believed that under better conditions of heat treatment which can be obtained with longer kilns and with a somewhat different arrangement of the combustion chamber, slightly better yields than those reported can be obtained. It should be remembered that the kiln used in these experimental trials was originally designed for burning cement, but this type of kiln has long been superseded by improved forms. In order to get the proper heat treatment in the middle of the kiln to complete the reaction, it was necessary to have the upper part too hot. This condition will not maintain in a properly-designed kiln. It is also believed that the use of oil as fuel would have allowed an easier regulation of the heat treatment, but the trials so far undertaken have been made under conditions which were found available at the time.

The subject of the costs of this process and of the product cannot be gone into in detail at this time, but a few general statements may be made. The production of water-soluble potash in feldspathic rock is essentially a low-grade proposition, and the commercial success of such a process depends upon the low cost of the various operations. The manufacture of a straight potash fertilizer containing as valuable ingredients only potash and lime must be carried out on a very large scale and by the most modern methods of continuous operation. With regard to the clumping process, the trials have shown that this operation can be practically carried out as a continuous process and at an exceedingly low charge per ton of product.

The process may be directly compared with that of the manufacture of Portland cement. It is a little easier to grind feldspar and lime than the shales and limestones used in cement manufacture. Drying will cost no more. Chemical control of the raw mixes will not be more expensive, and perhaps much less. Clumping, as has been shown, adds a very small charge to the expense of treatment. The cost of furnacing the feldspar mix will be less than similar charges in the cement industry, as the temperatures required are much lower and less coal is consumed. The product from the potash kiln is comparatively soft and pulverizes easily in hammer mills, while the charges on the cement industry for grinding clinker are an important item. Again, the softer potash product merely requires to be ground fine enough for use as a fertilizer, whereas cement clinker must be ground very fine and costs rise rapidly with increasing fineness. Repair bills in the case of feldspar treatment should be much smaller than in cement manufacture. The charge for raw materials is somewhat larger than in the case of cement, but this is more than met by the smaller costs of operation.

The potash fertilizer as now produced should be the equal in fertilizing value of the ordinary grades of hardwood ashes. The product carries practically the same content of water-soluble potash and somewhat more lime than wood ashes. There is every reason to believe that if the process becomes an industry the yields of water-soluble potash can be considerably improved. The material yielded is not a fused product; it is friable as an ash, and it has the physical texture to make it a valuable aid to soil structure. The success of the product must, of course, depend upon the results obtained under test conditions in its experimental use as a fertilizer. If results are obtained which are as good as, or better than, those which usually attend the proper use of high-grade wood ashes, it is believed that there should be no reason why this product cannot be successfully produced and introduced, especially in those parts of the country where potash feldspars, fuel, and shipping facilities are available.

SUMMARY.

In this paper a summary is given of the various processes which have been proposed for making the potash in the natural silicates available as a fertilizer.

Experimental trials of a new rotary kiln process for treating feldspar are described, which depends upon a previous treatment before furnacing, consisting of a method of aggregating or clumping the mix so that chemical contact of the reacting substances is brought about during the subsequent processing. The qualitative and quantitative results obtained on a number of experimental trials on a mill scale of operation are presented and discussed. It is shown that it is possible to economically manufacture a potash fertilizer containing free lime from feldspar, and for a sufficiently low cost to make an industry based upon the method worthy of consideration.

A METHOD OF IMPROVING THE SENSITIVENESS OF THE TELEPHONE RECEIVER AS A DETECTOR IN ALTERNATING CURRENT NULL MEASUREMENTS.

BY

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THE numerous applications of the electrostatic condenser have lately directed attention to the necessity for a quick and accurate method of measuring the capacity of such condensers. It is generally recognized that condensers whose dielectrics are materials of low cost and of good mechanical working quality usually have electrical characteristics that seriously impair the accuracy and reliability of direct current measurements of their capacity. The presence of appreciable polarization, of residual effects, or of leakage, causes the apparent capacity as obtained by direct-current methods to be quite different from the true or Maxwellian capacity. It is true, in the case of standard condensers made from a good quality of mica, that there is substantial agreement between the results obtained by various methods; but even in this case there will always be differences, so that for the highest precision it is necessary to calibrate such condensers on circuits having characteristics similar to those of the circuits upon which the condensers are afterward to be operated.

It has been found that an alternating-current bridge measurement is most reliable in all cases, since the true capacity, unaffected by leakage, by polarization, or by dielectric loss, is directly determined. More exactly, the unknown capacity is found in terms of the known capacity of a standard or reference condenser. Moreover, since the capacity balance of the bridge cannot be obtained without a simultaneous phase balance, the same measurement affords knowledge of the phase angle of the tested condenser, and hence of the energy loss in the material comprising the dielectric. But the success of this method depends upon the detector used to indicate when the bridge is balanced. In comparing condensers of similar characteristics, for instance two good mica condensers, the ordinary high-resistance telephone receiver is quite serviceable when testing on circuits of frequency not lower than 150 cycles per second; but the telephone receiver is extremely insensitive at commercial frequencies. Moreover, when commercial condensers are to be compared with reference condensers, which latter usually have a good grade of mica as dielectric, the exaggeration of any harmonics that may be present in the testing voltage wave, and the periodic shifting of phase of the poorer condenser, make it extremely difficult to secure a balance at the fundamental frequency, which cannot coincide with the point of balance for any one of the harmonics.

The ideal detector is, of course, the vibration galvanometer. Failing this, a mechanical rectifier with a direct-current galvanometer will give good results; but either of these devices requires for satisfactory operation a stand or table practically free from vibration. This can be secured, in more or less cumbersome ways, but the attention and expert manipulation required make these detectors suited primarily for use in the laboratory.

This paper is intended to describe a modification of the telephone detector, which the author has found extremely sensitive, and which does away with the difficulties and limitations ordinarily encountered in using the receiver as a detector. It is a fact that the human ear, although quite sensitive to a high-pitched musical tone when subjected to that tone only, becomes unable to detect the exact point of extinction of this tone when higher harmonics or overtones are present. But if another tone, slightly differing in pitch from the fundamental, be impressed at the same time, the ear will at once recognize the discord. This is true even when the discordant tones are both extremely faint; in fact, it seems to be evidenced that the most delicate sensibility prevails when this condition is realized. If, then, a steady, feeble tone of slightly different frequency from that of the testing voltage be impressed on the ear, the fact that the bridge is balanced will be indicated by the absence of "beats," although there may be still present quite audible tones due to various harmonics. This was accidentally noticed by the author during a bridge comparison of two mica condensers. An alternating-current arc lamp was being operated on the floor below, and the slight hum from the arc, coming to the ear through an opening in the floor, developed plainly audible beats when the bridge was slightly out of balance.

Several cheap and simple applications of this scheme are at once obvious. In a laboratory it will generally be found that a tuning-fork is at hand, whose frequency is but slightly different from that of the test circuit. It is best to choose a fork of higher frequency, and bring the latter down, by the addition of weights, to the required value. By arranging a very simple make-and-break contact on the fork, which may be hand- or electrically-driven, beats can be obtained by holding the test receiver to one ear, and holding to the other ear a second receiver in circuit with a single dry cell, a resistance of suitable value, and the tuning-fork make-and-break contact. The hands may be left free to manipulate the bridge, if operators' or head-type receivers are available.

In a commercial test, as carried out in a manufacturing plant, a small induction motor will generally be available. If this is of the squirrel-cage type, it may be arranged to drive a small alternator, the voltage from which will differ in frequency from that impressed on the motor sufficiently to be used in this way. If a wound type motor with slip rings is at hand, it may be driven at slow speed in any convenient way, when the voltage from the slip rings will have the desired slight difference of frequency from that impressed on the stator windings. It will be found that the ear is most sensitive to a discord giving from three to six beats per second.

The chief usefulness of this device is on circuits of frequency below 150 cycles per second; say on 25- or 60-cycle circuits, where the telephone receiver *per se* is quite useless as a detector. This method of beats will be found surprisingly sensitive; in fact, other things being equal, the sensitivity depends only upon the difference in frequency between the two tones, and it seems possible that frequencies above the audible limit may be available by the use of a modification of this method.

In conclusion, it may be said that but one obstacle presents itself to the use of this method in commercial testing; namely, the difficulty of securing a quiet place for the test. But a simple device which will secure an air-tight connection between the receiver and the outer ear will overcome this difficulty. The author has found that moistening the ear with a damp handkerchief will cause the receiver to make a sufficiently tight connection.

RECAPITULATION.

This paper describes a method of employing the watch-case telephone receiver in the comparing of capacities by the alternating-current bridge method. The use of this scheme does away with the difficulties ordinarily encountered in attempts to use the receiver in this way. The success of the method is due to the fact that the human ear is much more sensitive to a noise or sound of very low frequency, in the presence of a barely audible note of high frequency, than to the latter alone. By this method, which is here denominated the "method of beats," such a receiver may be used to balance an alternating-current capacity bridge:

(1) On frequencies too low to sensibly affect the ear.

(2) In cases where the time-constant balance is a function of the current strength in the bridge circuit.

Simple means are suggested for the ready application of the method to commercial as well as to laboratory measurements.

WILKINSBURG, PA., November 9, 1912.

Color of Brass. ANON. (*Brass World*, viii, 9, 330.)—The composition of brass may be approximately determined by its color.

Brass containing 5 per cent. zinc—red.

Brass containing 10 per cent. zinc—bronze color.

Brass containing 15 per cent. zinc—light orange.

Brass containing 20 per cent. zinc—greenish - yellow (green brass).

Brass containing 25 per cent. zinc—greenish - yellow (green brass).

Brass containing 30 per cent. zinc—true yellow brass color.

Brass containing 35 per cent. zinc—true yellow brass color.

Brass containing 40 per cent. zinc—reddish-yellow.

Brass containing 45 per cent. zinc—rich golden color (orange).

Brass containing 50 per cent. zinc—richer golden color.

Brass containing 55 per cent. zinc—like 14-karat gold.

Brass containing 60 per cent. zinc—yellowish-white.

Brass containing over 60 per cent. zinc—white and then gray.

Or, very soft brass, red or orange, contains 10 to 15 per cent. zinc, greenish-yellow brass contains 20 to 25 per cent. zinc, brass of the true brass color contains 30 to 38 per cent. zinc, and hard brass, of orange-yellow color, contains more than 38 per cent. zinc, and less than 60 per cent.

THE ESTIMATION OF PHENOL IN CRUDE CARBOLIC ACID AND TAR OILS.[1]

BY

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A PROBLEM which is occasionally presented to the chemist engaged in the examination of various tar products is the determination of actual phenol (C_6H_5OH) in the substance under consideration. Usually all that is required is the estimation of total phenols, generally called " tar acids." These tar acids consist of a complex mixture of phenol, cresol, and various higher homologues, and their quantitative estimation *in toto* is always based on their common chemical property of solubility in a solution of caustic alkali. Sometimes, however, it is necessary to proceed further, and ascertain how much of these tar acids is real phenol.

At present, so far as the writer has been able to learn, there is no satisfactory solution of this problem in the literature. Many tests for qualitative distinction of phenol, cresol, and the higher homologous oxygenated aromatic hydrocarbons have been proposed. Some of these are of very doubtful value, even qualitatively, but none are all susceptible of even approximate quantitative application.

The only real attempt in this field was that of Charles Lowe (see Lunge's Coal Tar and Ammonia, Fourth Ed., pp. 608–9). This is proposed for crude carbolic acid, and is more a specification for material than a method of analysis. Briefly, it consists in plain distillation in a retort, with no attempt at fractionation, and subsequent determination of the melting point of an arbitrary fraction. This fraction is a definite volume per cent. after removal of the water. The percentage of phenol is determined by adjusting a mixture of phenol and cresol (mixture of the three isomers) to have the same melting point. This is a method evidently only applicable when the percentage of phenol is large and when there is no disturbing influence of higher homologues.

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[1] Communicated by the author. See also " Note on the Rideal-Walker Phenol Control," by J. T. A. Walker and J. M. Weiss, JOURNAL FRANKLIN INSTITUTE, 174, 101.

The writer, in attacking this problem, decided that chemical properties would be inferior to physical properties as a means of distinction, in view of the fact that the material sought existed in mixture with bodies very closely related chemically to it. To separate phenol from all bodies except the next higher homologues, the cresols, is a comparatively simple task, and one which can be accomplished in a convenient and easy manner. Further, if the physical properties of a large number of varying mixtures of phenol and cresols are known, the estimation of the phenol is possible, the exactness varying with the number of such known mixtures. This really is the gist of the work undertaken by the writer, and the practical results of the investigation are presented in this paper.

The work was complicated by the fact that the three isomeric cresols exist with varying physical properties, and the possibilities of mixtures with four variables are enormous. This phase of the question, as will be seen later, was considerably simplified.

As a preface, it may be well to give the physical properties of phenol and the cresols, as taken from Van Nostrand's Chemical Annual:

	Melting point.	Boiling point.	Specific gravity.
Phenol	42.5°–43° C.	182.6°	1.0677
o Cresol	30°	191°	1.0511
m Cresol	3–4°	202°	1.0390
p Cresol	36°	202°	1.0390

The specific gravities are given for the cresols at 15°/15° and for phenol at 35°/35°. Beilstein gives the following figures:

	Melting point.	Boiling point.	Specific gravity at 0° C.
Phenol	42.5°–43° C.	178.5°–184.1°	1.0906
o Cresol	30°	190.8°	1.0578
m Cresol	3°	202.8°	1.0498
p Cresol	36°	201.8°	1.0522

As may be seen, the specific gravities and boiling points of *m* and *p* cresols are quite close together, and these two always occur together in commercial mixtures; therefore, to simplify matters, a mixture of these was used instead of the pure separate materials, thereby reducing the variables to be considered to three. The *m* and *p* cresols cannot be separated by physical means, and to prepare them pure is a very extensive and difficult task. As to the accuracy of the above figures given by various authorities for the physical constants of these substances, the writer feels that in many cases they are inaccurate and will take up this phase of the subject later.

The phenol used was prepared synthetically from pure benzene, the *o* cresol by fractional extraction of a mixture of cresol, with caustic soda solution, subsequent crystallization from petroleum ether, and final fractional distillation. The mixture of *m* and *p* cresol was separated by a very careful and efficient fractionation of a fraction of but two or three gallons taken from a works still handling large charges. The tests of these materials are given below:

	Phenol.		*o* Cresol.		Mixture of *m* and *p* cresol.	
Solidifying point	40.5° C.		27.75°		Below —10° C.	
Specific gravity 25°/25°			1.0429		1.0313	
Boiling point range ...	179°	first drop	189°	first drop	198°	first drop
	180°	1%	190°	19%	199°	2%
	181°	92%	191°	93%	200°	6%
	182°	100%	192°	100%	201°	81%
					202°	100%

To obtain some idea of the purity of these substances, the effect of 5 per cent. of *o* cresol or the *m–p* cresol on the phenol boiling point was determined, as follows:

95% phenol, 5% *o* cresol.		95% phenol, 5% *m* – *p* cresol.	
177°	first drop	178°	first drop
178°	2%	179°	7%
179°	4%	180°	10%
180°	9%	181°	23%
181°	88%	182°	85%
182°	96%	183°	93%
184°	100%	185°	97%
		190°	100%

Similarly, *o* cresol with 5 per cent. phenol addition had a range in boiling point of from 186° to 192° C. The method for taking boiling-point range was a distillation of 100 c.c. in a Jena flask protected by an asbestos ring and connected to a 24-inch condenser. Naturally, there is a certain lag of the thermometer at the start and a slight superheating at the end which tends to enlarge the range, even of a pure substance. The presence of a trace of water, hard to avoid in such hygroscopic substances, also causes a slight amount of material to distil below its true boiling point. On the phenol, practically 90 per cent. boiled between 180° and 180.5°, and no fraction could be obtained having a higher solidifying point than 40.5° C., no matter how many times it was distilled. The same was true of the ortho-cresol on distillation—no fraction could be obtained with a solidifying point over 27¾° C. These solidifying points were taken on a large quantity of material with the thermometer in the liquid. The thermometer was a Jena glass normal thermometer that has been checked by the United States Bureau of Standards. The writer therefore considered his materials practically absolute, and deemed that the high figures given by earlier investigators as to melting point were inaccurate either because of erroneous thermometers or from the use of too small quantities of material.

A large number of mixtures were made with the above materials, using 0, 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, and 95 per cent. phenol, and for each percentage of phenol eleven variations of the proportions of *o* and *m–p* cresols were used, making in all 132 mixtures. The boiling-point range, specific gravity, and solidifying point of all these mixtures were then determined.

For the purposes of this paper it is unnecessary to detail all the figures obtained on these mixtures, but only to give those which would be of practical value to the worker. It was found that for all but unusual cases the determinations of solidifying point and specific gravity were enough to characterize the mixtures as to their percentage of phenol, and that a determination of boiling-point range was superfluous.

The procedure for determining the percentage of phenol in a crude carbolic acid or a tar oil should be as follows: A definite volume of material should be taken, sufficient to give 300 c.c. of total phenols (tar acids). This should then be treated with sufficient caustic soda solution to dissolve all tar acids. The solution of acids in soda is carefully separated from the neutral hydrocarbons and then steam-distilled until no oil is present in the distillate. This insures the removal of all material not tar acids. The soda solution is then cooled, brought into a separatory funnel, and acidified with 40° Baumé sulphuric acid. The mass is allowed to settle, and the lower layer of sodium sulphate discarded. The upper layer of phenols is brought into a distilling flask with a Hempel tube, and distilled up to 170° C. vapor temperature. This removes water, but a small amount of acid is carried over in the process. This latter is separated from the water and returned to the flask. The distillation is then continued, and two fractions taken off, the first up to 190° C. and the second from 190° C. to 202° C. This second fraction is redistilled, taking all up to 197° C., and is added to the 190° fraction obtained in the first distillation. This combined fraction contains all the phenol and none of the homologues above cresol, and is tested for solidifying point and specific gravity.

The solidifying point is taken on about 50 c.c. in a test-tube with the thermometer in the liquid and cooling until separation of crystals occurs. At this point there is a constant temperature for a short period which is taken as the solidifying point. If the material supercools, crystallization may be brought about by addition of a minute crystal of phenol: in this case the temperature rises as the crystals separate, and the highest point reached is taken as the solidifying point. The specific gravity should be taken on a Westphal balance at 25° C. and referred to water at the same temperature.

These figures are compared with those given below, the per cent. of phenol noted, and the result figured back to the original material. In considering these figures, it should be remembered that *o* cresol tends to simultaneously raise both the specific gravity and melting point of a mixture, and therefore up to a certain point with increase of melting point the gravities corresponding to the same percentage of phenol also increase.

Various mixtures which may occur as a result of the above procedure are given in a rough classification.

Solidifying point below 0° C.:

Specific gravity $\frac{25}{25}$.	Per cent. phenol.
up to 1.032	0
1.035	5
1.040	10
1.043	20
1.047	30
1.049	40

Mixtures above 40 per cent. phenol have a solidifying point over 0° C.

Solidifying point 0–5° C.:

Specific gravity $\frac{25}{25}$.	Per cent. phenol.
up to 1.038	0
1.040	5
1.042	10
1.045	20
1.048	30
1.052	40

Solidifying point 5–10° C.:

Specific gravity $\frac{25}{25}$	Per cent. phenol.
1.039	0
1.041	5
1.043	10
1.047	20
1.050	30
1.053	40
1.055	50

Solidifying point 10–15° C.:

Specific gravity $\frac{25}{25}$.	Per cent. phenol.
1.040	0
1.042	5
1.044	10
1.048	20
1.051	30
1.054	40
1.057	50

Solidifying point 15–23° C.:

Specific gravity $\frac{25}{25}$.	Per cent. phenol.
1.041	0
1.043	5
1.045	10
1.048	20
1.052	30
1.055	40
1.058	50
1.061	60

Solidifying points above 23° C.:

Solidifying point ....23.5°............Phenol 70%
Solidifying point ....29.5°............Phenol 80%
Solidifying point ....32.75°...........Phenol 85%

Solidifying point ....35.5°............Phenol 90%
Solidifying point ....37.75°...........Phenol 95%
Solidifying point ....40.5°............Phenol 100%

With solidifying points above 23° C. it was found that the variations in percentage of the cresols among themselves did not affect the solidifying point for any particular percentage of phenol.

Some mixtures would not be covered correctly by the above tables. For example, a mixture of 20 per cent. phenol and 80 per cent. *m–p* cresol melts below 0° and has a gravity of 1.040. This would indicate, as above, only 10 per cent. phenol. But such a mixture could *never* occur in a fraction obtained from natural materials, and therefore it is unnecessary, for practical analysis, to cover this ground. If it were necessary, the boiling points would be distinguishing, but to introduce these constants would make complications, and would not be of practical value for the purposes this paper is designed to cover.

In using these tables, the worker must exercise some judgment, as if a solidifying point were barely over 0° C. and the specific gravity were 1.040 at 25° C., the percentage of phenol would be more than 5 per cent. and less than 10 per cent., and about 7.5 per cent. should be taken. Conversely, near the upper end of a range of solidifying point the gravity would indicate slightly less phenol than the figure given. If the figures are used intelligently and with real insight into their meaning, an estimation on the *fraction* within 2.5 per cent. of the true value should be readily obtained. Depending upon the total amount of tar acids in the original material, the results on the basis of the latter should be accurate between 0.2 per cent. and 1.5 per cent., and this is sufficiently close for all ordinary purposes.

The Disturbing Influence of Solar Radiation on the Wireless Transmission of Energy. Nikola Tesla. (*Elec. Rev. West. Elect.*, lxi, 34.)—The weakening of the impulses in wireless transmission is not due to ions liberated by sunlight, but to the evaporation of water on the hemisphere of the earth toward the sun, the conducting particles carrying off into the ground more or less of the electrical charges imparted. The Tesla system of transmitting energy through the earth is contrasted with the Herzian wave system.

Collection of Radium Emanation from Spring Waters. H. Greinacher. (*Univ. Zurich Phys. Zeit.*, xiii, 435.)—In collecting water samples, loss of the emanation is avoided by the use of an exhausted glass globe with a glass stopcock instead of the ordinary container. The emanation is separated by boiling the water in the glass globe while it is directly connected to a partially-exhausted fontactoscope suitably modified. The use of the exhausted container insures the collection of water samples without loss of the emanation by inexperienced persons.

Meeting of the International Radium Standard Commission in Paris. O. Hahn, St. Meyer, and E. v. Schweidler. (*Physik. Zeit.*, xiii, 524.)—A sample of pure anhydrous radium chloride prepared by Mme. Curie, and weighing 21.99 mg., was compared with three standard samples of radium chloride of the highest purity prepared by O. Hoenigschmid, of the Radium Research Institute of the Imperial Academy of Sciences of Vienna, weighing, respectively, 10.11, 31.17, and 40.43 mg. The activities of the several standards were found to agree within the limits of experimental error, 2 parts per 1000. Mme. Curie's standard was declared the official international standard, and is to be kept in the International Bureau of Weights and Measures in Sèvres, Paris. The Imperial Academy of Sciences of Vienna will be requested to deposit one of its standards, weighing 31.17 mg., in Vienna, as a supplementary standard. The commission formulated regulations for providing governments with secondary standards.

NOTES FROM THE U. S. BUREAU OF STANDARDS.

COPPER WIRE TABLES.[1]

THIS circular discusses the results of work recently completed at the Bureau on the temperature coefficient and the conductivity of copper, as well as previous standard values, and gives a history of wire gauges, showing that the trend of practice is toward expressing diameter directly in decimal fractions of an inch.

There are fifteen tables, including complete reference tables for standard annealed copper, American Wire Gauge, both in English and in metric units; and similar abbreviated "working tables." There are also tables for bare concentric cables of standard annealed copper and for hard-drawn aluminum wire. The tables also include comparisons of wire gauges, and tables of temperature reductions, with complete explanations.

Four appendices give additional information—the first on the units used in the expression of resistivity; the second on the calculation of the "resistivity-temperature constant" and on the expression of the temperature coefficient; the third on the density of copper; and the fourth on the calculation of the resistance and mass per unit length of cables.

The status of the "Annealed Copper Standard" is given in paragraph 3 of the revised edition of this circular, as follows:

Ever since the American Institute of Electrical Engineers adopted the temperature coefficient, 0.0042 at 0°C., which vitiated the old wire table, the need for a new table was felt; and a recomputation of the old one had been under consideration. The need of more modern and representative data upon which to base the table had, however, been recognized, and the Bureau of Standards was requested to secure such data. The work was done in the first half of 1910, and reports of the investigations were presented to the Standards Committee of the Institute. At its meeting of October 19, 1910, that committee requested the Bureau of Standards to prepare copper wire tables, based on the investigations, to replace the old wire table of the Institute. As a result of this action, a complete set of tables was prepared. On October 14, 1910, also, the United States Committee of the International Electrotechnical Commission voted that steps should be taken to interest the Commission in the subject of an international standardization of copper standards, and accordingly the question of standardizing the temperature coefficient was submitted to the other national committees by the United States national committee in letters of January 26, 1911. The question of a standard conductivity was considered by the national committees of several nations in September, 1911; and the result was an agreement among the representatives of Germany, France, and the United States to recommend a value proposed by Germany, differing only slightly from the value recommended by the Bureau and adopted by the Standards Committee of the American Institute of Electrical Engineers. The values for the temperature coefficient determined at the Bureau and corroborated at the German Reichsanstalt were accepted. For the standard resistivity thus defined, the name "Annealed Copper Standard" is proposed.

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[1] Circular of Bureau of Standards No. 31, revised edition.

In order to facilitate the establishment of an international standard, and at the request of the Standards Committee of the American Institute of Electrical Engineers and the United States Committee of the International Electrotechnical Commission, the publication of the copper wire tables was withheld and they were recomputed on the new basis. This circular and its tables are the result. These tables give a concrete idea of the application of the proposed international copper standards. These standards have received widespread approval for international adoption since their suggestion about a year ago, and no other values have been proposed in the meantime for international consideration. Hence it seems very probable that in the event of international agreement these will be the numerical values adopted. If international agreement is not attained, the Bureau of Standards will make no further change in the numerical values. Hence, in either event, no further change of the basis of the Bureau is to be expected. In its certificates of tests of copper wire the Bureau will give per cent. conductivities both on the proposed international basis and on the old basis until January 1, 1914.

It is probable that the new standard will have been adopted internationally before the date mentioned, and it is hoped that manufacturers, testing laboratories, and others concerned will have revised their standards in conformity with the new standard by that time. The various societies concerned have not as yet had an opportunity to act upon the matter, but the committees of some of them have considered and approved the proposed standards. As mentioned, the Standards Committee of the American Institute of Electrical Engineers has recommended them. The Copper Wire Committees of the American Society for Testing Materials, although opposed to changing the standard, have agreed to recommend their adoption when made international. The Wire and Cable Subcommittee of the Verband Deutscher Elekrotechniker has recommended them. The International Committee on Rating, of the International Electrotechnical Commission, has adopted a formal resolution recommending the proposed international standards to all countries. It is expected that the various national and international societies will act upon the recommendations during 1913.

Tungsten. ANON. (*Brass World,* viii, 9, 328 (from *Le Mois Scientifique.*)—Tungsten is used to make tungsten steel, filaments for incandescent electric lamps, and in the manufacture of projectiles. Tools made of tungsten steel do not soften when subjected to high temperatures and to the heaviest work. Tungsten alloys used for "high-speed" tools contain from 10 to 25 per cent. tungsten. Tungsten pure enough to be drawn to very fine wire is made by reducing its compounds in a vacuum furnace by the aid of hydrogen. These filaments have a greater conductivity than carbon filaments and give increased luminosity and at the same time consume less current. Tungsten 98½ per cent. pure is sold to-day for 50 cents per pound.

Starch Converted into Dextrin by X-Rays. H. A. COLWELL and S. RUSS. (*Phys. Soc. Proc.,* xxiv, 217.)—Solutions of starch in distilled water exposed to X-rays of moderate penetrating power in a dish covered with a thin sheet of mica were partly converted into dextrins, 5 per cent. of dextrin was formed in 8½ hours. This change might also have been produced by hydrolysis; but, according to Kernbaum, X-rays do not decompose distilled water, so that the X-rays, or the secondary rays to which they give rise, would appear to act directly on the starch molecule. Solutions of dextrins were not converted into glucose by X-rays under similar condition

Color Photography by Prismatic Dispersion. J. and E. RHEINBERG. (*Phot. Journ.*, lii, 162.)—The apparatus and methods for this process are described as follows: (1) The real image is focused upon an opaque screen with narrow, transparent, parallel lines; (2) this real image is focused upon the photographic plate by a lens and prism which give for each point of each transparent line a microspectrum more or less incomplete, according to the local coloration of the object photographed; (3) the development of the photographic negative of these microspectra; (4) the production of a black-and-white transparency positive of the same; (5) the use of the positive as a screen in superposition to a series of complete microspectra produced by optical means in the camera, which is used as an instrument for viewing the picture. Each complete microspectrum is more or less cut off by the screen, and the result is a distribution of color in the field of view, reproducing the original colors. The history of the idea is given, and a detailed discussion of the optical requirements, such as plates, exposure, etc., adjustments, methods of viewing, and the possible further developments.

High Pressure Gas for Heating Furnaces. A. W. ONSLOW. (*Engineering*, xciii, No. 2424, 810.)—The best results are obtained by keeping the gas at constant pressure, and drawing in air under atmospheric conditions. If the pressure is steady, any heating furnace can be calibrated and desired conditions attained with certainty after the lapse of sufficient time to get the furnace thoroughly heated. Working at any definite pressure, a curve of furnace temperature plotted against time will always give a substantially straight line till the point of constant temperature corresponding to that pressure be reached. If the pressure be raised, the temperature will continue to rise until the new constant temperature point be reached. Thus it is possible to tabulate conditions for any heating furnace. A properly-designed gas furnace can be prepared from the cold state in a much shorter time than a coal furnace. In small work this may be a reduction of hours to minutes, and in large work of days or weeks to hours. The use of tiles of refractory material as baffles raises the temperature and gives better distribution. Pressures suitable for typical work are: For melting tin or solder a pressure of 65 inches is suitable, and that is also good for hardening in small furnaces. For bluing steel, from 65 to 80 inches is good. For the lead-pot for tempering steel the pressure should be 150 inches, while for melting metals at 2000° to 2600° F. it should be 200 inches. There is still needed a cheap yet efficient means of compressing the gas to the supply pressure of about 200 inches. Satisfactory heating burners are available, and the various phenomena on which economical and uniform working is dependent are now fairly understood.

FRANKLIN INSTITUTE

(*Proceedings of the Stated Meeting held Wednesday, November 20, 1912.*)

VICE-PRESIDENT COLEMAN SELLERS, JR., *in the Chair.*

Additions to membership since last report, 9.

The paper of the evening was presented by Alfred Noble, C.E., LL.D., of New York, entitled, "The Railway Tunnels of New York City."

A brief historical review of early tunnel projects served as an introduction, which was followed by a detailed description of the tunnels which are now in use in the city of New York.

The most approved systems of tunnelling, the various methods of carrying on the work without interference to traffic, and the obstacles met in tunnel construction, were given consideration.

The paper was fully illustrated by numerous lantern slides of engineering details and views of tunnels in various stages of construction.

At the close of the paper the Chairman extended the thanks of the Institute to the speaker, and the meeting adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, November 6, 1912.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 6, 1912.

DR. GEORGE A. HOADLEY *in the Chair.*

The following report was presented for first reading:

No. 2520.—De Vos' Rolling Sector Boat Davit. Advisory. Adopted.

The following was accepted for examination:

No. 2521.—The Hoover Suction Sweeper.

R. B. OWENS,
Secretary.

SECTIONS.

Mechanical and Engineering Section.—A meeting of the section was held on Thursday evening, October 24, 1912, at 8 o'clock, in the Hall of the Institute.

Mr. George R. Henderson, Chairman.

The Chairman introduced Mr. James Donald, Consulting Naval Architect to the Fore River Shipbuilding Company, Quincy, Mass., who read a paper on "Safety of Life at Sea."

The paper was discussed by Messrs. G. W. Dickie, Haig, Swan, and Rigg, Naval Constructors Snow and Leonard, and other naval architects present.

A vote of thanks was tendered Mr. Donald.

Adjourned.

FRANK B. STEM,
Secretary.

Physics and Chemistry Section.—A meeting of the section was held in the Hall of the Institute on Thursday evening, November 7, 1912, at 8 o'clock.

Dr. Harry F. Keller occupied the Chair.

The Chairman introduced Prof. Russell H. Chittenden, Director, Sheffield Scientific School, Yale University, who delivered a lecture on "The Chemistry of Nutrition."

Dr. Chittenden spoke chiefly on the influence of the character of proteins on growth and development in animal life. He contrasted the former methods of comparing food values by chemical analysis only, with the present-day methods of the physiologist, whose field of endeavor lay in the determination of the effect of enzyme and other action on the assimilation of foods.

After a brief discussion the thanks of the meeting were extended Dr. Chittenden.

Adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

Mining and Metallurgical Section.—A meeting of the section was held on Thursday evening, November 14, 1912, at 8 o'clock, in the Hall of the Institute.

The meeting was called to order by the president of the section, Prof. Alexander E. Outerbridge, Jr.

After a few introductory remarks on the rapid development, in commercial use, of the electric furnace, the Chairman presented Mr. F. A. J. FitzGerald, A.B., B.S., of the FitzGerald & Bennie Laboratories, Niagara Falls, N. Y., who spoke on "Experimenting with the Electric Furnace."

Mr. FitzGerald described, with diagrams and photographs, the various forms of arc and radiation furnaces he had experimented with. He also spoke of electrodes, of induction regulators, pyrometers, and other important details in electric furnace work.

He exhibited samples of refractory materials used in lining furnaces, including Kieselguhr and carborundum bricks.

After a brief discussion, in which Dr. Hering and Mr. Clamer participated, the thanks of the meeting were extended to Mr. FitzGerald.

Adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

MEMBERSHIP NOTES.

Elections to Membership.

RESIDENT.

Mr. Chas. J. Allen, Fifth and Glenwood Avenue, Philadelphia.
Dr. David W. Horn, Box 12, Bryn Mawr, Pa.
Mr. Edwin Walker Kelly, 5450 Pine Street, North Philadelphia.
Mr. R. T. Markee, Sixty-fifth and Woodstock Streets, Germantown, Philadelphia.
Mr. Walter Palmer, Y.M.C.A., Chester, Pa.
Mr. Julian Stern Simsohn, 909 North Franklin Street, Philadelphia.

NON-RESIDENT.

Dr. Henry Spencer Blackmore, Mt. Vernon, N. Y.
Mr. John P. Donohoe, 599 North Main Street, Greensburg, Pa.
Mr. V. A. Suydam, Princeton, N. J.

LIFE.

Col. M. Richards Mucklé, 1722 Pine Street, Philadelphia.

Changes of Address.

Mr. Carl G. Barth, 6151 Overbrook Avenue, Overbrook, Pa.
Mr. Calvin F. Crowell, 237 East Main Street, Moorestown, N. J.
Mr. Frank Shaw Clark, Stone & Webster, 147 Milk Street, Boston, Mass.
Mr. Arthur D. Edgerton, Box 377, Marshfield, Ore.
Mr. Charles H. Fish, P. O. Box 1593, Boston, Mass.
Mr. A. Sonnin Krebs, 2340 Ash Street, Denver, Col.
Mr. C. P. Landreth, 640 North Eighth Street, Philadelphia.
Mr. Carlton Williams, Blackwood, Camden County, N. J.
Dr. George Woodward, Chestnut Hill Academy, Chestnut Hill, Penna.

Necrology.

Mr. Chas. W. Buchholz, 50 Church Street, New York City, N. Y.
Mr. Horace H. Furness, Wallingford, Delaware County, Pa.
Mr. Clement A. Griscom, P. O. Box 1569, Philadelphia, Pa.
Mr. J. N. Pew, Morris Building, Philadelphia.

NECROLOGY.

Charles Waldemar Buchholz, late consulting engineer to the Erie Railroad Company and member of The Institute since 1899, was born in Prussia sixty-nine years ago. He attended the technical school and gymnasium at Stettin until his seventeenth year, when, upon the death of his parents, following a natural inclination he made two voyages around the world. He came to America during the Civil War, in 1864, entered the Navy, and was honorably discharged at the close of the war, ranking as ensign for meritorious service. He then entered the employ of the Reading Railroad, and rose with this company from transit man to chief engineer of construction. In 1885 he was appointed chief engineer of the Erie Railroad. He held this office until 1892, when he accepted the position as president and chief engineer of the Quaker City Elevated Railroad of Philadelphia. He served in this capacity until the following year, when he returned to the Erie road. He continued as chief engineer to this road until 1903, when he was appointed consulting engineer—a position he held until his death.

He thus saw forty-seven years of active service as a railroad engineer, during seventeen of which he was connected with the Erie Railroad as its chief engineer.

Mr. Buchholz was a member of The Franklin Institute, the American Society of Civil Engineers, and of the Engineers and Transportation Club of New York, etc. He was a representative to the International Railway Congress at Berne, Switzerland, July, 1910.

Clement A. Griscom was born in Philadelphia in 1841. He was educated in the public schools of the city, and attended the Central High School for two years. At the age of sixteen he entered the shipping house of Peter Wright & Sons as a clerk and, by his unusual energy and ability, won quick promotion. When but twenty-two years old he became a partner in the firm. He gave particular attention to the various steamship enterprises it was interested in, and became a leading authority on both transatlantic and coastwise traffic.

In 1871 the International Mercantile Marine was organized and he was elected as its vice-president. He continued as such until 1888, when he succeeded James A. Wright as president. This concern passed through a remarkable development, and in 1902 it was reorganized and its name changed to the International Mercantile Marine Company. Mr. Griscom was chosen head of the new corporation, and continued in that position until 1904, when he resigned to become chairman of the Executive Board. He was, in addition, active in numerous other fields of finance. He was a director of the Pennsylvania Railroad Company, the United States Steel Corporation, United Gas Improvement Company, as well as of numerous banks and savings funds societies.

He was decorated by foreign royalties in recognition of his success in the organization of the transatlantic service.

Mr. Griscom was a member of The Franklin Institute since 1889.

LIBRARY NOTES.

Purchases.

ALLEN, C. F.—Field and Office Tables Specially Applicable to Railroads. 1912.
ALLEN, G. T.—Tables of Parabolic Curves. 1898.
BABBAGE, C.—Table of Logarithms of the Natural Numbers 1–108,000. 1889.
BAKER, C. H.—Brewing Calculations. 1897.
BAKER, T. T.—Simple Chemical Experiments. 2nd edition. n.d.
BARTLEY, B. C.—Marine Engineer's Record Book. 1897.
BATE, A. H.—Principles of Electrical Power. 1905.
BELLASIS, E. S.—Punjab Rivers and Works. 1912.
BUCKLEY, R. B.—Irrigation Pocket Book. 1911.
BYROM, T. H., and J. E. CHRISTOPHER.—Modern Coking Practice. 1910.
CANTELL, M. T.—Reinforced Concrete Construction. 1911.
CHARLETON, A. G.—Gold Mining and Milling in Western Australia. 1903.
COLLINS, H. F.—The Metallurgy of Lead. 2nd edition. 1910.
GERHARDI, C. H. W.—Electricity Meters. n. d.
GOLDINGHAM, A. H.—The Gas Engine in Principle and Practice. 1912.
GRAHAM, J.—Elementary Treatise on the Calculus. 1905.
HATFIELD, W. H.—Cast Iron in the Light of Recent Research. 1912.
HUEBNER, J.—Bleaching and Dyeing of Vegetable Fibrous Materials. 1912.
KEPPY, F.—Injectors. 1909.
MARLOW, T. G.—Drying Machinery and Practice. 1910.
MORGAN, A. P.—How to Build a 20-Foot Bi-plane Glider. 1909.
MORRISON, C. E., and O. L. BRODIE.—High Masonry Dam Design. 1910.
OLANDER, E.—Graphic Strains and Girder Construction. 1887.
POULSEN, A.—Cement in Seawater. 1909.
PRICE, W.—Turner's Handbook on Screw-cutting. 1912.
SCHNEIDER, N. H.—Electrical Circuits and Diagrams. 1904.
SCHNEIDER, N. H.—Study of Electricity for Beginners. 1906.
SHELFORD, F.—Pioneering. 1909.
STRANGE, W. L.—Indian Storage Reservoirs with Earthen Dams. 1904.
TAYLOR, F. H.—How to Use Electric Light. n. d.
TULLY, C. E.—Locomotive Slide Valve Setting. 1903.
VIGNIER, R. M. DE.—Model Steam Engine Design. 1911.
WAKEMAN, W. H.—Refrigeration, Ice-making and Refrigerating Machinery. 1907.
WRIGHT, F. B.—Inventions: How to Protect, Sell, and Buy Them. 1911.
XYDIS, C.—Handbook on Tacheometrical Surveying. 1909.

Gifts.

Isthmian Canal Commission, Canal Record, vol. v, 1911–12. Washington, D. C., 1911–12. (From the Commission.)
Canada Department of Mines, Mines Branch, Report on the Building and Ornamental Stones of Canada. Ottawa, 1912. (From the Department.)

London Meteorological Committee, 7th Annual Report. London, 1911. (From the Committee.)

Willans & Robinson, Inc., Catalogue of Steam Turbines and Diesel Oil Engines. Rugby, 1912. (From the company.)

U. S. Bureau of Foreign and Domestic Commerce, Department of Commerce and Labor, Imported Merchandise Entered for Consumption in the United States during the year ending June 30, 1912. Washington, 1912. (From the Division of Publication.)

Institution of Civil Engineers of Ireland, Transactions, vol. 38, List of Members, 1911–12. Ireland, 1912. (From the Institution.)

Baltimore & Ohio Railroad Company, 86th Annual Report. Baltimore, 1912. (From the company.)

Manchester Association of Engineers, Transactions, 1911–12. Manchester, 1912. (From the Association.)

Institution of Engineers and Shipbuilders of Scotland, Transactions, 1911–12. 1912. (From the Institution.)

Riefler, S.—"Tabellen der Luftgewichte, und der Gravitation." Berlin, 1912. (From the author.)

Ohio Inspector of Mines, Annual Report 1911. Columbus, 1911. (From the Inspector.)

Australia Commonwealth, Official Year Book, 1912. Melbourne, 1912. (From the Statistician.)

Missouri Bureau of Geology and Mines, The Iron Ores of Missouri. Jefferson City, 1912. (From the Bureau.)

Minnesota Historical Society, Collections 1912. St. Paul, 1912. (From the Society.)

North of England Institute of Mining and Mechanical Engineers, Report of Council, 1911–12. Newcastle-upon-Tyne, 1912. (From the Institute.)

Pennsylvania Museum and School of Industrial Art, Annual Report. Philadelphia, 1912. (From the School.)

Minnesota Railroad and Warehouse Commission, Annual Report, 1891–1903. Minneapolis, 1891–1903. (From the Commission.)

Vermont State Library, Finding List, Legislative Reference Department. N. p., n. d. (From the Library.)

Staffordshire Iron and Steel Institute, Proceedings 1911–12. Stourbridge, 1912. (From the Institute.)

PUBLICATIONS RECEIVED.

Les canalisations isolées. Conferences faites a l'Ecole Supérieure d'Électricité par J. Grosselin, Ingenieur civil des Mines. 96 pages, illustrations, plates, 8vo. Paris, Gauthier-Villars, 1912. Price, in paper, 3 francs 75c.

Celluloid: Its Manufacture, Applications, and Substitutes, by Masselon, Roberts and Cillard. Translated from the French by Herbert H. Hodgson, M.A., B.Sc., Ph.D. 356 pages, illustrations, plates, 8vo. Philadelphia, J. B. Lippincott Company, 1912. Price, in cloth, $7.50

Freezing-point, Boiling-point, and Conductivity Methods. Second edition, completely revised by Harry C. Jones, Professor of Physical Chemistry, in the John's Hopkins University. 75 pages, illustrations, 12mo. Easton, Pa., Chemical Publishing Company, 1912. Price, in cloth, $1.

An Inductive Chemistry, by Robert H. Bradbury, A.M., Ph.D., head of the Department of Science, Southern High School, Philadelphia. 415 + 21 pages, illustrations, portraits, 12mo. New York, D. Appleton & Co., 1912.

Laboratory Studies in Chemistry, by Robert H. Bradbury, A.M., Ph.D., head of the Department of Science in the Southern High School, Philadelphia. 129 pages, illustrations, 12mo. New York, D. Appleton & Co., no date.

Canada Department of Mines, Mines Branch: Report on the Building and Ornamental Stones of Canada, by Wm. A. Parks, B.A., Ph.D. Vol. I, 376 pages, illustrations, plates, maps, 8vo. Ottawa, Government Printing Bureau, 1912.

U. S. Bureau of Mines: Bulletin 43, Comparative Fuel Values of Gasoline and Denatured Alcohol in Internal-Combustion Engines, by R. M. Strong and Lausen Stone. 243 pages, illustrations, 8vo. Miners' Circular 9, Accidents from Falls of Roof and Coal, by George S. Rice, 16 pages, 8vo. Technical Paper 24, Mine Fires: A Preliminary Study, by George S. Rice. 51 pages, 8vo. Washington, Government Printing Office, 1912.

Mesure de l'Équilibre des circuits téléphoniques par M. Béla Gáti ingenieur en chef des télégraphes de Hongrie. Extrait des Annales des Postes, Télégraphes et Téléphones (September, 1912). 8 pages, illustrations, 8vo. Paris, A. Dumas, no date.

Sugar at a Glance: Charts and data prepared by Truman G. Palmer concerning national economy and the high cost of living as affected by the increased yield of other crops when grown in rotation with sugar beets. Senate document No. 890, 62nd congress, 2nd session. 67 pages, illustrations, plates, 4to. Washington, 1912.

Canada Department of Mines: Summary report of the Mines Branch of the Department of Mines for the calendar year ending December 31, 1911. 208 pages, illustrations, plates, maps, 8vo. Ottawa, Printer to the King, 1912. Price, in paper, 10 cents.

BOOK NOTICES.

CHEMISTRY FOR BEGINNERS, by Edward Hart. Published by the Chemical Publishing Company, Easton, Penna. 214 pages, 12 x 16 cm. Price, $1.

The inexhaustible profusion in which elementary text-books of chemistry pour from the press is a remarkable fact. There is nothing about this book to differentiate it from the texts already in the field. Very much better books are available, and also very much poorer ones.

The text is not divided into chapters. There is to be a second volume, dealing with Organic Chemistry. The book is to be used without a laboratory manual, the experiments being distributed through the text. Many of the experiments require rather elaborate apparatus, and would be too difficult and dangerous for high schools. On the other hand, the descriptive and theoretical portions seem rather elementary for college students.

Slips are by no means absent. The candle of the Pasteur filter is not made of earthenware, and it is not necessary or desirable to heat it red hot in order to clean it (p. 26). The account of the manufacture of calcium nitrate from the atmosphere (p. 45) is very brief, but what there is of it is totally erroneous. In the historical account of the discovery of oxygen the name of Carl Wilhelm Scheele is not mentioned (p. 3). Experiment 141 (p. 102) would be dangerous in the hands of the beginner. The treatment of electrolysis and ionization is very inadequate (pp. 119–124). The diagrams of the Bessemer process cannot be understood from the description, while the open-hearth process, which at present furnishes about twice as much steel as the Bessemer, is dismissed in three lines (p. 179). The discussion of colloids is almost entirely confined to the rather ponderous (and, to the beginner, quite unnecessary) terminology of the subject, the epoch-making facts regarding molecular motion being ignored. The table of the periodic law (p. 204) is antiquated. The difficulty about placing the inert gases was solved years ago, and its solution constitutes one of the most striking triumphs of the periodic conception. ROBERT H. BRADBURY.

A CONCISE HISTORY OF CHEMISTRY, by T. P. Hilditch. Published by D. Van Nostrand, New York, N. Y. 263 pages, 12 x 19 cm. Price, $1.25.

The appearance of short books of this type is to be accepted as an encouraging proof of the growth of interest in the historical side of chemical science. The present book is accurate and, in the main, well done. It bears the unmistakable marks of being intended for the use of students preparing for examinations in the subject. Too many topics are merely mentioned, and two few are adequately discussed. This gives some portions almost the appearance of a catalogue or a syllabus. In the reviewer's opinion, a subject should either be described in an intelligible way or be entirely omitted. However, it is impossible to follow this rule in a text intended for students preparing for examination. The book is well written and should be useful to the class for whom it is intended.

ROBERT H. BRADBURY.

PROBLEMS IN PHYSICAL CHEMISTRY, by E. B. R. Prideaux. Published by D. VanNostrand, New York, N. Y. 311 pages, 13 x 21 cm. Price, $2.

This is a unique and valuable book. The problems offered cover the whole field of physical chemistry. Some of the topics handled are "Units," "The Phase Rule," "Thermochemistry," "Gas Reactions," "Electromotive Force," "Molecular Kinetics," and "Radioactivity." Some of the questions are sufficiently difficult to test the powers of even the advanced student. The answers are given in all cases.

The knowledge gained from text-book and lecture is, at first, almost wholly verbal. It is not really a part of the student's mental equipment, and he may be able to talk fluently about a subject and yet be unable to make any use of the information he has acquired. The working-out of problems is one of the best methods of accelerating the transformation through which all knowledge must pass before it can actually be employed for practical purposes. The student who has been carefully drilled upon a book like Morgan's "Physical Chemistry" and has, at the same time, worked his way through a selection of the problems in the present book will have more real knowledge of the subject than one who has listened to innumerable lectures.

ROBERT H. BRADBURY.

CHEMISTRY OF FOOD AND NUTRITION, by H. C. Sherman. Published by the Macmillan Co., New York, N. Y. 355 pages, 12 x 19 cm. Price, $1.50.

We have already noted the appearance of Professor Sherman's "Organic Analysis." The present volume takes up the subject of foods entirely from the view-points of Physiological Chemistry and Dietetics. "It is hoped that the more detailed description of individual foods and the chemical and legal control of the food industry may be treated in a companion volume later." This is a book which can be recommended with confidence to any one interested in the subject. The treatment is simple and intelligible, but entirely scientific. The author is completely familiar with the literature, and there is a freedom from fads and unsupported statements which, in a work dealing with Dietetics, is noticeable. There is a good index.

ROBERT H. BRADBURY.

ALLEN'S COMMERCIAL ORGANIC ANALYSIS, 4th edition. Published by P. Blakiston's Son & Co., Philadelphia.

Vol. IV, "Resins, Rubber, Gutta-percha, and Essential Oils," edited by W. A. Davis and S. S. Sadtler. 461 pages, 15 x 23 cm. Price, $5.

Vol. VI, "Organic Bases and Vegetable Alkaloids," edited by W. A. Davis and S. S. Sadtler. 721 pages, 15 x 23 cm. Price, $5.

This standard work is rapidly approaching completion. Only two volumes remain to be published, of which Vol. VII, which deals chiefly with vegetable and animal chemistry, is in press. Like those which preceded them, the present volumes have been rewritten and now contain an authoritative and complete account of the subject. The book is indispensable to the commercial analyst or, indeed, to any one whose analytical work is concerned with the organic side of the science. ROBERT H. BRADBURY.

HISTORY OF BRIDGE ENGINEERING, by Henry Grattan Tyrrell, C.E., Graduate of Toronto University, Bridge and Structural Engineer. 478 pages, illustrations, plates, 8vo. Chicago, Author, 1911. Price, $4.

Wherever a river and highway intersect some device is necessary for the crossing. It may be by a bridge above the stream, by a ferry on its surface, or by a tunnel underneath. Hence the ingenuity of man has been taxed from the earliest ages in devising structures for passing streams under all conditions. Their name is legion, and it is not only interesting but of great value to have available the graphic record of these works in condensed form.

Such a compilation has been made by Henry Grattan Tyrrell, C.E., of Evanston, Ill., published by himself, and issued from the press of G. B.

Williams Company, of Chicago. It contains some 400 pages, including an index of over 500 bridge builders and engineers and a subject list, based on locations, of more than 2000 structures, including nearly all types, excepting movable and military bridges.

Such a mosaic is the result of extended research and will serve as an admirable aid to the architect or engineer, who may thus obtain a comprehensive idea of the great range in style, material, and cost.

There are some 300 illustrations, taken from photographs, drawings, or diagrams in side elevation, showing in general the superstructure, but not the foundations, nor details, as these pertain to the science of construction, while this work is necessarily limited rather to the evolution of the art in its empirical stages than to the subsequent development of the scientific problem by Fairbairn, Brunel, Stevenson, Haupt, Whipple, and their successors, as embraced in the illustrious names in the index.

Although many long-span, wooden and stone bridges were built which were remarkable for their beauty and stability from the stand-point of the architect, it was not until after the introduction of railroads that the necessity for greater strength, economy, and rapidity of erection demanded a scientific analysis of the stresses in the several members and the corresponding distribution of the materials. This phase of the subject is not treated in this " History," which is confined to the completed structures. The demand for iron bridges on the Pennsylvania Railroad led to the rapid evolution of the science by the Chief Engineer of the company.

This book is timely and will fill a void in the general library of the engineering student.

Lewis M. Haupt.

CURRENT TOPICS

Vanadium in Chile, Argentina, and Peru. DAILY CONSULAR REPORT. (*Brass World*, viii, 9, 322.)—One of the Chile silver mines contains a valuable deposit known as Chileite, a brownish mineral containing 7.5 per cent. of vanadium, the use and importance of which is becoming greater every day. At Talcuna vanadium occurs in the form of a yellow earth between veins of copper ore, and near Cordova it is found in veins containing more than 5.5 per cent. of metal. Vanadium also occurs in rocks containing carbonaceous material. In Argentina lignite is found which yields 0.63 per cent. of ash containing over 21 per cent. of vanadium. A lead vanadate containing 14 per cent. of vanadium is found in the State of Cordova; it is black in color, with a yellow streak. An alloy of steel with only 0.25 per cent. of vanadium has a very high tensile strength and range of elasticity.

New Case Hardening Compound. P. W. BRENNAN. (*Brass World*, viii, 9, 310.)—The compound as patented by Mr. Brennan consists of

Potassium cyanide	2 ounces
Sodium bicarbonate	1 ounce
Potassium bicarbonate	1 ounce
Bone dust	½ ounce

The ingredients are powdered and mixed. The iron or steel to be case-hardened is heated and covered with the mixture, after which it is again heated to a bright red and plunged into water. The depth of the case hardening may be regulated by the number of times the iron or steel is heated with the mixture.

Atmospheric Ozone. H. N. HOLMES. (*Amer. Chem. Journ.*, xlvii, 497.)—The starch and potassium iodide reaction is given by ozone, hydrogen peroxide, and nitrogen peroxide. The effect of hydrogen peroxide is greatly accelerated in the presence of ferric sulphate, and nitrogen peroxide can be recognized by special tests. As a rule, the atmosphere contains only enough ozone to give the starch reaction; hence this reaction may be used for the ozone test in the atmosphere. The maximum amount of ozone is found when rapidly-moving areas of high barometer are so near the observer that quantities of air from great altitudes rapidly flow down to the earth. Most of the ozone is produced by the solar ultra-violet rays of the upper atmosphere; thunderstorms are of minor importance as generators of ozone.

Fire Tests with Glass. ANON. (*Engineering,* xciii, 2426, 874.)—The British Fire-Prevention Committee has recently published in No. 166 "Red Book" a report of two tests of "copperlite" glazing, supplied by Hayward Brothers and Eckstein, Limited, of London. The object of the first test was to record the effect of fire of 60 minutes' duration, the temperature to reach 1500° F. but not to exceed 1650° F., followed by the application of water for two minutes on the fireside, with the view of being classed as affording temporary protection (Class B). In the second test the object was to record the effect of a fire of 90 minutes' duration, the temperature to reach 1500° F. but not to exceed 1800° C. (*sic,* probably F. is meant), followed by the application of water for two minutes on the fireside, with the view of being classed as affording partial protection (Class A). In the first case neither fire nor water passed through the glazing, and the result was the same in the second case, so the classification desired was granted.

Corrosion of Steel in Water. G. J. BURROWS and C. E. FAWSITT. (*Roy. Soc., New South Wales, Journ.,* xlv, 67.)—It is believed that the first stage in the process of rusting is the solution, to a limited extent, of the iron in the water, with the formation of ferrous ions. The hydrogen thus produced, in the absence of free oxygen, polarizes the surface of the iron; then the function of the oxygen is the removal of the layer of polarizing hydrogen. If this be so, contact with a more electronegative metal, like platinum, should increase the speed of rusting. Experiments made to test this theory, using uniform steel strips fully immersed in unstirred distilled water, showed that such strips, when connected with platinum, rusted more rapidly than under ordinary circumstances. The steel used had the composition: 0.35 per cent. carbon, 0.61 manganese, 0.06 phosphorus, 0.01 silicon, and 0.01 sulphur. Experiments to test the influence of the composition of steel on the velocity of rusting in water containing 2.64 grammes sodium bicarbonate, 0.113 grammes magnesium sulphate, and 0.166 grammes sodium chloride per litre gave irregular results, from which few exact conclusions could be drawn. It was, however, noticeable that the initial rate of corrosion is very different from the rate developed after a few weeks, and that a steel containing from 0.9 to 1.0 per cent. of carbon rusts to a lesser extent than steels containing a smaller percentage of carbon. Magnetization has no noticeable effect on the corrosion of a steel of the composition given above. In discussing the work of Heyn and Bauer on corrosion, the authors state that the accelerative effect of salts on corrosion is explained by the greater conducting power of the solution, and that the decrease in the velocity of rusting with higher concentrations is probably due to the decreased solubility of oxygen in the solution.

Rotating Cathode. C. W. BENNETT. (*Journ. Phys. Chem.*, xvi, 287.)—The author has designed a revolving cathode which can be rotated at a speed up to 6,000 revolutions per minute, and which will carry 300 ampères, giving a current density of about 3,500 ampères per square foot when 4 inches of the cathode is receiving a deposit. This cathode is so arranged that the deposited metal can be removed for testing in suitable pieces without bending or heating. If the deposited cylinder is required as a whole, a thin shell of fusible metal is first cast around the cathode, and after the electrolysis the whole is immersed in boiling water. The full details of the construction are given.

Action of Ultra-violet Light on Chlorine. E. B. LUDLAM. (*Phil. Mag.*, xxiii, 757.)—As ultra-violet light ejects electrons chiefly from electropositive elements, though also from electronegative oxygen, the author tried the highly electronegative chlorine gas, which has a band in the ultra-violet, which band might prevent the ejection of electrons. According to Lenard, who conducted part of the research, a shorter wave-length is necessary to produce ionization in oxygen than is required to convert oxygen into ozone. The wave-lengths tried with chlorine and also with air ranged from 440 to 90 $\mu\mu$. There was very little ionization produced even in dry air by waves exceeding 200 $\mu\mu$; with wave-lengths below 180 $\mu\mu$ there was considerable ionization of pure dry air, which was enormously increased by a trace of water. Very small quantities of chlorine also increase the ionization of air, more chlorine stops it. Pure chlorine is not appreciably ionized, and does not form condensation nuclei when the illuminated gas is forced to impinge against an orifice from which a jet of steam issues. Considerable quantities of chlorine destroy any ions and condensation nuclei otherwise formed in the air. Thus chlorine does not appear to lose an electron easily, and traces of foreign matter appear necessary for the ionization of gases and for their chemical combination; yet actual liberation of electrons for a measurable period of time does not appear to be a necessary precursor of gaseous combinations.

Telephotography. O. WHEELER. (*Photogr. Journal*, lii, 62.)—A discussion of the usual formulæ employed in telephotography is given. It is suggested that advance in this branch of photographic work may be expected in the following directions: (1) High magnification, (2) special screens for long-distance work, (3) instantaneous telephotography, especially with reference to aërial reconnaisance, (4) panoramic telephotography, (5) color work. The use of compound tel-negatives is also discussed. During the discussion the relative merits of the hood and of a dead-black lining to the lens tube received considerable attention.

Contraction of Antimony-Lead and Aluminum-Zinc Alloys during and after Solidification. D. EWEN and T. TURNER. (*Rev. de Métallurgie,* viii, 728.)—During solidification antimony expands considerably, while lead does not change in volume. Their alloys show two maxima, one at the eutectic point, and the other at 50 per cent. lead; and two minima. The curve cannot be reconciled with the thermal equilibrium diagram nor with the Shore hardness diagram. In the aluminum-zinc series the expansion curve showed a maximum at the eutectic point, and in the remainder of the curve there appears to be a relation between the expansion and the solidification interval. Shore hardness tests and tensile strength tests indicate the existence of maxima in these values at 20 per cent. and 50 per cent. aluminum. The tensile strengths observed agree closely with those found by Bancroft. Cooling curves of alloys containing 2.4 to 60 per cent. of aluminum show a critical-point between 200° and 300° C., which reaches a maximum when the alloy corresponds to the composition $AlZn_2$. When quenched from 300° C. the alloy of this composition shows no eutectic point.

Capacity in Three-phase, Three-core Cables. A. B. CLARK. (*Elec. Rev.,* lxx, 532.)—The author proves from first principles how it is possible from two measurements of the capacity between certain elements of a three-core cable to deduce all other capacity values. All the requisite formulæ are proved, and the test results obtained show that they are in perfect accordance with experiment.

Autoclave Boiling Test for Concrete. H. J. FORCE. (*Eng. News,* lxvii, 1111.)—In the United States failures developed in concrete which had passed the ordinary test of boiling in water at atmospheric pressure, and these autoclave tests were made in consequence thereof. Briquettes of cement which had passed the ordinary test were covered with water in the autoclave and the steam pressure raised to 285 pounds per square inch in 45 minutes. After 1¼ hours further exposure the pressure was relieved. Some briquettes had swelled and they crumbled on removal; others, tested when cool, showed as much as 145 per cent. increase in tensile strength. The percentage water absorptions, the percentage expansions, and the fineness in a 100- and 200-mesh sieve were measured. The results are so conclusive that one of the railroads has adopted the autoclave test. The tests show that only the fine material in the cement enters into the reaction of setting, and to make the whole mass set the larger particles must be broken up. Age causes this to occur in large concrete structures with consequent disintegration. The claim that the failure to pass these tests is due to lime or free magnesia is rejected. Increasing the fineness of unsound cement improves its quality, and in every case the cement becomes sound if the material is sufficiently fine.

Cobalt-Carbon System. G. BOECKER. (*Métallurgie,* ix, 296.)—By heating pure cobalt with sugar charcoal in magnesia crucibles in an electric carbon-tube furnace alloys were prepared containing up to 3.9 per cent. carbon, which appears to be the saturation-point of cobalt for carbon at the temperature of 1700° C. Observation of the cooling-curves shows that the melting-point of cobalt, 1448° C., is lowered to a eutectic point at 1300° C. with 2.9 per cent. carbon. At 1300° C. the saturated solid solution contains 0.82 per cent. carbon, but as the temperature falls the solubility diminishes, and at 1000° C. only about 0.35 per cent. carbon is retained in solution. On slow cooling the carbon separates in the graphitic condition. These conclusions are confirmed by micrographic analysis.

Crystallization and Structure of Slowly-cooled Steel. N. T. BELAIEW. (*Rev. de Métallurgie,* ix, 321.)—The crystallization and structure of iron-carbon alloys containing less than 2 per cent. of carbon were studied. All the alloys were kept molten for two hours, and then allowed to cool slowly, so that 60 hours elapsed while the temperature fell from 1500° C. to 300° C. During this slow solidification "primary crystallization" occurs with the production of interlocking dendrites built up of octahedral crystals. When conditions are favorable this dendritic structure is visible to the naked eye, and it can always be developed by the prolonged etching of polished specimens. The decided indications are that the resulting solid solution is not homogeneous. During the solid solution range of temperature neighboring octahedra of similar orientation aggregate to form polygonal grains. At the eutectoid temperature the so-called secondary crystallization takes place, depositing ferrite or cementite, which forms envelopes for the pearlite grains and gives rise to the cellular structure. The secondary crystallization is markedly influenced by the foregoing phenomena. If the secondary crystallization occurs very rapidly, the structural constituents, ferrite and cementite, arrange themselves parallel to the four surfaces of the octahedron and form Widmanstätten figures inside the grains. This combination of the net-work and Widmanstätten figures has been termed the Widmanstätten structure. The examination of the structure of isolated crystals, which have developed in cavities, shows that the axes of dendrites coincide with the lines of deposition of the ferrite and cementite. Such a structure is called the "structure of large crystals."

Electrolytic Preparation of Persulphate. A. BLUMER. (*Zeitsch. Electrochem.*, xvii, 965.)—Experiments were made with M. Le Blanc's anode, consisting of four rings of platinum wire, held by a skeleton-cylinder of glass rods, and two electrode tubes of mercury. The details scarcely admit of abstraction.

The Ammonia Flame. A. C. EGERTON. (*Nature,* lxxxix, 270.)—Ammonia burning in oxygen gives a yellow flame, resembling the nitrogen glow of Strutt, and with a similar spectrum. The ammonia seems first to be split up into nitrogen and hydrogen, and the inner, bright yellow cone of the flame is apparently due to the combination of nitrogen atoms to molecules, as in the nitrogen glow; while in the outer, hardly luminous cone, the hydrogen is burned to water, and some nitric oxide is formed. Flames due to the combination of substances generally have a pointed cone, whilst in the ammonia flame the inner cone assumes a rounded apex.

Solubility of Wrought Tungsten and Molybdenum. W. E. RUDER. (*Amer. Chem. Soc. Journ.,* xxxiv, 387.)—Tests were made on discs of sheet tungsten, 18 mm. in diameter and 2 mm. thick, with hydrochloric, sulphuric, nitric, and hydrofluoric acids, aqua regia, alkaline carbonates, and potassium hydroxide. At room temperature the first three acids, whether concentrated or dilute, have no effect, except dilute nitric acid, which forms a yellow, surface oxide. Fused potassium hydroxide attacks the metal slowly. Hot or cold hydrofluoric acid does not attack tungsten, but does attack tantalum; but mixed hydrofluoric and nitric acid dissolves tungsten, forming tungstic oxide. Molybdenum is much more easily dissolved than tungsten. It resists concentrated hydrochloric and sulphuric acid below 1250° C. fairly well, and is not attacked by hydrofluoric acid.

Central-station Power for Municipal Pumping. ANON. (*Elect. Rev. and West. Electn.,* lx, 1033.)—In this article the principal advantages of central-station power for municipal pumping are pointed out, with comments on important pump and motor characteristics, which should be considered when changing over to electric drive; and gives comprehensive data on a large number of plants now working satisfactorily. Two types of pump should be considered for driving by electric motors—the various forms of the plunger type, and the centrifugal type. The plunger type is usually triplex, and either single- or double-acting, and is a little more efficient than the other; but it is essentially a low-speed machine, limited to about 30 revolutions per minute. Therefore it requires speed reduction, and thus increases cost and adds complexity. On the other hand, the centrifugal pump can be directly connected to motors operating at their normally high speeds, up to about 1,500 revolutions per minute, and thus is low in first cost, compact, and easily operated. Furthermore, centrifugal pumps are suited to direct-pressure service. Both types give reliable and satisfactory service when used under those conditions to which they are essentially adaptable.

Spectrum of the Brooks Comet (1911c). A. DE LA BAUME PLUVINEL and F. BALDET. (*Comptes Rend.*, cliv, 1286.)—During the time the comet was visible 22 good spectrograms were obtained with a specially-designed prismatic camera. Important changes in the spectrum were observed as the distance from the sun varied; but these changes were confined to the nucleus only. There was evidence that the sodium lines, and perhaps the iron lines, became stronger in the spectrum as the comet approached the sun. Further, as the sodium lines became stronger the Swan carbon spectrum diminished in intensity. The negative pole spectrum of nitrogen was apparently absent from the spectrum of this comet.

Sealing Metals. P. E. SHAW. (*Phys. Soc. Proc.*, xxiv, 95.)—Threlfall used Margot's solder (92 per cent. tin, 8 per cent. zinc) to fasten glass, aluminum or quartz surfaces to any other. Other solders are found efficient, viz., tin, zinc, various alloys of tin and zinc, tinman's solder, and aluminum. Besides these, there are many materials with melting points between 180° and 660° C. For these and similar materials which act like sealing-wax, the name "sealing-metals" is suggested. They have the advantage over wax in high melting-point and the non-emission of vapor at high temperatures.

Developments in Steam Turbine Engineering. E. D. DREYFUS. (*West. Soc. Engin. Journ.*, xvii, 413.)—This article is a *résumé* of progress in turbine design, showing the special work for which different designs are most applicable; and the variations in construction dependent on working conditions and the capacities required. In a few years the range of capacities in use has been extended from 1 to 20,000 kilowatts per machine; and now turbines of 30,000 horse-power are being built. The single-disc wheel construction is used up to 300 kilowatts; such small turbines are largely used for auxiliary service, excitation, pumps, etc. Reference is made to the variety of systems of governing low-pressure turbines, and the design of a convertible type of low-pressure turbine is illustrated. It is a single-flow reaction element with a provision for the introduction of a high-pressure impulse wheel when conditions require it. The pressure relations between reciprocating engines and turbines in a combined system are considered, and the curves of combined water-rates of a given engine and low-pressure turbine with varying load are given. Many designs are illustrated, among them an automatic "bleeder" turbine for combined electrical and steam-heating loads, and the relation of steam distribution and power load with the variable bleeding demand is diagrammatically illustrated. Various methods of applying turbines are referred to and illustrated, such as several arrangements of the Leblanc condenser applications, and centrifugal pump and blower designs.

Railway Equipments. K. SIMMON. (*Elect. Rwy. Journ.*, xxxix, 1111.)—In this article some recent experiences are recorded. It is pointed out that motors are often geared too high, and that in some cases it is economical to lower the gear ratio. Other improvements in motors are referred to, and it is shown that mere reduction of weight may be carried too far and results in frequent repairs. Many improvements lately introduced are mentioned, such as multiple-unit control, field control, low platform cars, high voltage direct current, and the single-phase systems. It is expected that there will be in future a considerable extension of the multiple-unit system of control.

Examination of Eggs by X-Rays. ANON. (*Rev. Sci.*, 1, 25, 791.)—The Roëntgen X-rays are now used for determining the condition of eggs (candling). At the place where the eggs are received a dark room is arranged with a Crookes tube set in a lantern, hermetically sealed except one aperture just large enough to enclose a hen's egg. The egg is placed in this aperture and exposed to the X-rays. Fresh eggs are perfectly translucent; if a little old, a small spot is visible on the fluorescent screen; if the spot is large or if it moves about, the egg is bad, and is rejected. The larger egg merchants of London will only accept "examined eggs." By this method spots may be clearly seen which are so small as to be invisible to the naked eye.

A New White Non-corrosive Alloy. ANON. (*Mech. Eng.*, xxix, 411.)—This alloy consists of iron 30 to 70 per cent., nickel 25 to 50 per cent., and copper 5 to 20 per cent. It can be cast, rolled, and drawn. It is important to keep the carbon within 0.2 per cent. to prevent the formation of hard nodules. An alloy containing 65 per cent. iron, 25 per cent. nickel, 10 per cent. copper, and 0.2 per cent. carbon has an elastic limit of 51,750 pounds per square inch and an ultimate stress of 96,100 pounds per square inch, with an elongation of 42 per cent. in 2 inches, and a reduction of area of 53.7 per cent. In making the alloy a small amount of manganese or magnesium is used as a deoxidizer because of the low content of carbon.

Electricity Direct from Coal. W. RAMSAY. (*Elec. Rev. West Electr.*, lx, 692.)—By producing gas direct from the coal bed, it is expected to produce electricity by means of gas engines at the pits' mouth with a saving of 30 per cent. of the available coal energy, as against 15 per cent. now available in fuel engines. Concentric tubes through a bore-hole to the coal substratum would furnish a means of electrically igniting the coal, and, if steam be blown in, would give a mixture of hydrogen and carbon monoxide, or water gas, which would be used as fuel for the gas engines.

Electrical Properties of Crystals. Stratification and Capacity of Carborundum. G. W. PIERCE and RHYS D. EVANS. (*Proc. Am. Acad. Arts. Sci.*, xlvii, 793.)—The electrostatic capacity of carborundum crystals was measured by a method of charge and discharge. The capacity of one specimen was about 0.006 microfarad, and of another about 0.022. The existence of capacity in the crystal was found to be due to numerous alternate conducting and insulating strata within the crystal. These strata are visible with vertical illumination and moderate magnification. Photomicrographs are given in the article. The action of carborundum as a detector for electrical waves and as a rectifier for electrical currents, is independent of its action as a capacity. It will detect or rectify only when contact is made to one or more of the conducting strata. It may detect electrical waves with an adjustment that shows no capacity, but with every adjustment at which capacity was found there were also rectification and detection of electric waves.

Origin of Canadian Apatites. W. H. MCNAIRN. (*Trans. Can. Instit.*, viii, 495.)—Most of the apatite occurs in beds, intercalated with the Grenville limestone, in gneiss, accompanied by graphite, magnetite, anhydrite, etc. There are no true gangues. Its formation is reported to be: (1) Decomposing organic matter can absorb phosphoric acid from very dilute solutions. (2) Each phosphate stratum (except the true apatite) can be regarded as of direct or indirect organic origin. (3) Phosphates of known organic origin can unite with fluorine from water and form the true apatite molecule. (4) This process took place in early geologic times. (5) The enclosing rocks contain phosphoric anhydride, only in the form of apatite or as molecular admixtures. (6) The Canadian apatites occur in deposits which are in great part stratified. (7) Accompanying the apatite are anhydrite (undoubtedly sedimentary), calc-spar, gypsum, and magnetite, which have been formed apparently by organic means. (8) The coloring matter in the apatite and the accompanying limestone is organic. (9) The apatite crystals, and in a less degree the accompanying minerals, have been eroded later. The calc-spar contains detached parts of apatite. From the above the formation of Canadian apatites is traced as follows: (1) They are the final product of an accumulation of organic matter containing phosphoric anhydride, their content of which has been greatly augmented by the evaporation of sea-water. (2) The phosphates so formed remove fluorine from the water and thus form the true apatite. Fluorine was in many cases replaced by varying amounts of chlorine, forming the different varieties of apatite. Later changes finally gave the calcium fluophosphate its crystalline form. (3) The peculiar eroded appearance of apatite is attributed to the effect of calcium carbonate in a more or less fluid condition.

Weight of a Litre of Atmospheric Air at Geneva. PH. A. GUYE, J. KOVACS, and E. WOURTZEL. (*Rev. Sci.*, l, 25, 794.)—The weight of a litre of dry air, freed from carbon dioxide, was 1.2928 grammes, as weighed by Lord Rayleigh in London, 1.2927 Gm. weighed by Leduc in Paris, and 1.2930 Gm. weighed by Guye, Kovacs and Wourtzel, at Geneva, showing differences of $^2/_{10}$ and $^3/_{10}$ of a milligramme. This indicates that the mean density of the air varies in different localities, although within very small limits. This was verified by weighing three samples of air taken simultaneously at Geneva, at a height of 400 metres, at Mt. Salève, at 1280 m., and at Rochers de Naye, at a height of 2045 m. Thus the density of the air varies by some tenths of a milligramme at places not far apart.

The Action of Gelatine and Other Colloids in Retarding the Reduction of Silver Chloride. W. REINDERS and C. J. VAN NIEUWENBURG. (*Z. Chem. Ind. Kolloide*, x, 36.)—The speed of reduction of silver chloride by iron citrate, in the presence of gelatine and other colloids, depends on the nature of the colloid present and its concentration. In every case the speed was less than when no colloid was present, and decreased as the concentration of the colloid increased. Albumin decreased the speed of reduction most, then "Acid Violet 6B," gelatine, agar-agar, gum arabic, "Ponceau 3R," in the order named. The reduction is effected in two steps: solution of the solid salt, then reduction and crystallization of the reduced silver. It was shown experimentally that the presence of gelatine had no effect on the speed of solution of the silver chloride, but greatly affected the speed of crystallization from the solution.

Globoid Worm-Gearing. PEKRUN. (*Zeitschr. Vereines Deutsch. Ing.*, lvi, 442.)—Globoid worm-gearing, often called Hindley worm-gearing, is characterized by the fact that the pitch surface of the worm is not cylindrical, but a surface of revolution generated by the pitch-circle of the worm-wheel about the worm-axis. This form has practical advantages and was known to Leonardo da Vinci. The efficiency of the globoid worm is in general greater than that of the straight worm, which after running some time tends to wear to the globoid form. With worm-gearing of either of the above shapes the frictional losses are great. Hence the so-called Pekrun-gear was introduced, wherein the teeth of the worm-wheel are rollers, with axes in the plane of the worm-wheel and perpendicular to its axis. With this gearing, tests by several independent experimenters yield efficiencies of 93 to 95 per cent. Thus the position of agent and object can be interchanged at will, so that either large reduction or multiplication of speed can be obtained. In the latter sense the Pekrun gear has been applied to milk centrifugals.

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